AD NUMBER
AD827289
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; JAN 1968. Other requests shall be referred to Army Materiel Command, ATTN: AMCRD-RV-E, Washington, DC 20315. This document contains export-controlled technical data.**
AUTHORITY
AMC ltr dtd 22 Jul 1971

AD 827 289

TECHNICAL REPORT NO. 3-726 – 2

MOBILITY ENVIRONMENTAL RESEARCH STUDY A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY

Volume II

SURFACE COMPOSITION

by

R. C. Wright
J. R. Burns

January 1968

Sponsored by

Advanced Research Projects Agency
Directorate of Remote Area Conflict

Service Agency

U. S. Army Materiel Command

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

DISCLAIMER NOTICE

THIS DOCUMENT IS THE BEST QUALITY AVAILABLE.

COPY FURNISHED CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

AD-
927289

TAB-68-8

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI 39181

IN REPLY REFER TO: WESAR

28 February 1968

Errata Sheet

Technical Report No. 3-726

MOBILITY ENVIRONMENTAL RESEARCH STUDY
A QUANTITATIVE METHOD FOR DESCRIBING
TERRAIN FOR GROUND MOBILITY
Volume II
SURFACE COMPOSITION

January 1968

1. DD Form 1473, item 5, for Robert C. Wright, read Ramil C. Wright.

TECHNICAL REPORT NO. 3-726

MOBILITY ENVIRONMENTAL RESEARCH STUDY
A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY

Volume II

SURFACE COMPOSITION

by

R. C. Wright

J. R. Burns

January 1968

Sponsored by

Advanced Research Projects Agency
Directorate of Remote Area Conflict
Order No. 400

Service Agency

U. S. Army Materiel Command

Conducted by

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

FOREWORD

The study reported herein was performed by the U. S. Army Engineer Waterways Experiment Station (WES) for the Office, Secretary of Defense (OSD), Advanced Research Projects Agency (ARPA). This report describes portions of two tasks of the overall Mobility Environmental Research Study (MERS) sponsored by OSD/ARPA for which the WES was the prime contractor and the U. S. Army Materiel Command (AMC) was the service agent. The broad mission of Project MERS is to determine the effects of the various features of the physical environment on the performance of cross-country, ground-contact vehicles and to provide therefrom data that can be used to improve both the design and employment of such vehicles. A condition of the project is that the data be interpretable in terms of vehicle requirements for Southeast Asia. The funds employed for this study were allocated to WES through AMC under ARPA Order No. 400. The study was performed during the period June 1964-November 1965 under the general guidance and supervision of the MERS Branch of the WES, the staff element of WES responsible for the technical management and direction of the MERS program.

This volume is one of an eight-volume report entitled A Quantitative Method for Describing Terrain for Ground Mobility. These volumes are

- I: Summary
- II: Surface Composition
- III: Surface Geometry
- IV: Vegetation
- V: Hydrologic Geometry
- VI: Selected Air-Photo Patterns of Terrain Features
- VII: Development of Factor-Complex Maps for Ground Mobility
- VIII: Terrain Factor-Family Maps of Selected Areas

Field data were collected in Thailand between July 1964 and May 1965. Personnel who actively participated in the collection of surface

composition data during part or all of this period were: Messrs. C. A. Blackmon, MERS Thailand Detachment; J. E. Lee, A. J. Romano, G. T. Ellis, S. T. Hodge, and L. Jackson, Army Mobility Research Branch, Mobility and Environmental (M&E) Division, WES; R. D. Leighty, U. S. Army Cold Regions Research and Engineering Laboratory; and Chalaj Choeyapunt, Phayond Trushigone, Kasem Imkasorn, Manit Churanokoses, Wichai Winchienwidtya, Boontham Penchan, and Boonlip Sirimontaporn, Thai personnel employed by the MERS Thailand Detachment. Field sampling was conducted under the direction of Messrs. Blackmon, Lee, and Romano. Data reduction and map preparation were accomplished by a team composed of Messrs. J. R. Burns, team captain, G. E. Schabilion, and CPT R. C. Wright, Area Evaluation Branch, M&E Division. This volume was written by Mr. Burns and CPT Wright. The data reduction and map preparation were conducted under the direction of Mr. J. H. Shamburger, Geology Branch, Soils Division, WES. Mr. A. A. Rula, Chief, Mobility and Environmental Research Studies Branch, provided technical assistance in various phases of the work. All phases of this study were under the direct supervision of Mr. W. E. Grabau and Dr. C. R. Kolb, Chiefs of the Area Evaluation and Geology Branches, respectively, and under the general supervision of Messrs. W. G. Shockley and S. J. Knight, Chief and Assistant Chief, respectively, of the M&E Division and Messrs. W. J. Turnbull and A. A. Maxwell, Chief and Assistant Chief, respectively, of the Soils Division.

Directors of the WES during the conduct of this study and preparation of this report were COL Alex G. Sutton, Jr., CE, and COL John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
pounds per square inch	0.070307	kilograms per square centimeter

SUMMARY

This volume presents the methods used to collect, tabulate, and analyze basic data on surface composition of six selected Thailand study areas--Nakhon Sawan, Lop Buri, Chiang Mai, Pran Buri, Khon Kaen, and Chanthaburi. Fifteen mapping classes that expressed the different soil mass strength and soil surface strength conditions were established. The criteria used in isolating these classes were (a) that each class be identifiable using air-photo interpretation techniques and (b) that each class exhibit similar variations in strength with moisture content. Areas with equivalent trafficability characteristics in terms of the 15 map classes were delineated on 25 surface composition maps together covering the six study areas. This delineation was accomplished through interpretation of maps and air photos with control data in the form of field and laboratory information. The maps are presented in Volume VIII of this report.

A compromise between the desired degree of mapping class refinement and that dictated by the photo-interpretation criteria was necessary because of the nature of the field data. During the mapping program when sample site data were extrapolated to unsampled areas, the degree of mapping refinement was of necessity only fair to low. It is recommended that additional studies be conducted on the use of air-photo identification techniques in classifying soil strength conditions. This approach is believed to be basically sound; however, more field verification of predicted values will help to determine the reliability of this approach.

BLANK PAGE

MOBILITY ENVIRONMENTAL RESEARCH STUDY
A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY

VOLUME II: SURFACE COMPOSITION

PART I: INTRODUCTION

Background

1. The surface composition factor family is concerned with the composition and physical properties of the materials of the surface of the earth without regard to their origin. The study reported herein was concerned chiefly with classifying soils as an engineering material, excluding such materials as consolidated rocks, snow, and ice, although such materials are generally included in the surface composition factor family.

2. Strictly speaking, to classify soils is to arrange them into classes or groups according to a limited number of common characteristics. This presupposes that the characteristics have been first identified and described. Thus, the first step in classification is to identify the significant properties, then to measure or otherwise describe those properties, and finally to place all arrays of similar properties into categories that are meaningful for the purposes at hand. There are many systems for classifying soils currently in use; however, none is entirely adequate for mobility purposes.

3. The soil classification systems that presently appear to be most widely accepted for general engineering and mobility purposes are the Unified Soil Classification System (USCS) and the United States Department of Agriculture (USDA) system. The USCS is based on soil's textural, organic, and plasticity characteristics; the USDA system is based primarily on soil's texture, structure, consistency, and color. Usually it is necessary to obtain bulk samples of soils for laboratory analysis of textural, organic, and plasticity characteristics before reliable

classifications can be made. However, fairly consistent classification of soils can be made in the field by experienced personnel. Although procedures for describing and classifying soils according to the USCS and USDA system are not included in this report, they have been reported in detail.[1,2]

4. The most useful single soil measurement for ground mobility purposes is its shear strength. Physical soil properties (i.e. soil factors) that are known to influence the shear strength include moisture content, grain size, grain shape, mineralogical composition, organic content, plasticity, density, and structure (the way the soil particles are aggregated into compound particles). Of these factors, moisture content appears to be by far the most important, especially for fine-grained soils (>50% of the soil < 0.074 mm in diameter), or soils having a relatively large proportion of fine-grained materials (characterized by particles less than 0.074 mm in diameter).

5. A major objective of research in soils for engineering and mobility purposes is to develop methods of deducing shear strength from basic soil data. Since moisture content is so important, it follows that information on the effect of varying moisture contents on the shear strength of the various soil types is of paramount importance, and a method for predicting soil moisture content from weather or other data is essential. The U. S. Army Engineer Waterways Experiment Station (WES) has developed a method for predicting soil moisture content that is based on certain site and soil characteristics plus a percentage of the amount of rainfall by 24-hour periods. From a knowledge of soil type and moisture content, a reasonably good estimate of the shear strength (in terms of cone index) can be made.[3]

6. Experiments conducted to elucidate soil-vehicle relations have revealed that, for practical purposes, soil strength can be divided into two categories--soil mass strength and soil surface strength. Mass strength refers to the overall consistency or firmness of the soil from the surface down to about 12 to 15 in.* below the surface. It largely

* A table of factors for converting British units of measurement to metric units is presented on page vii.

governs the amount of sinkage a vehicle will undergo. Surface strength refers to the strength of a thin layer of soil, usually from the surface to about a 1-in. depth. This layer largely governs the amount of traction a given vehicle can develop on its first pass. Although it is often convenient to divide soil strength into mass and surface components for study purposes, it should not be inferred that such a division presently has rigorous application in the analysis of vehicle performance on soils. Much research remains to be done to clarify the complex interrelation of mass strength and surface strength and their separate and combined effects on vehicle performance.

7. The soil mass strength-vehicle relations for fine-grained soils have been investigated in detail, and procedures for predicting the effect of soil mass strength on vehicle performance have been developed for cases in which adequate soil surface strengths are present. Simple and reliable instruments for measuring soil strength are the cone penetrometer and the remolding equipment. A discussion of these instruments and the procedures for their use is presented in a Department of the Army Technical Bulletin.[4] The values measured with this equipment are the cone index (CI), which is an index of the shearing resistance of the soil, and the remolding index (RI), which is a ratio that expresses the change in strength that may occur under vehicular traffic. The product of the measured CI and RI for the same layer of soil is termed the rating cone index (RCI).

8. Soil surface strength has been less intensively studied than soil mass strength. As a result, less is understood about soil surface strength-vehicle relations than about soil mass strength-vehicle relations. The instrumentation required to obtain soil surface strength values is still very much experimental. A promising instrument, however, appears to be the Cohron sheargraph, which provides a rough measure of two soil shear strength parameters--cohesion and angle of internal friction. The values are computed from the instrument record of normal stress applied to the soil (in pounds per square inch) and shear stress (in pounds per square inch), which is the force required to rotate the sensing element of the instrument against the soil. A detailed discussion of both instrument and procedure is given by Cohron.[5]

Purpose

9. The overall purpose of this study was to (a) collect, tabulate, and analyze basic terrain data on surface composition, surface geometry, vegetation, and hydrologic geometry that would adequately describe the significant terrain variations occurring in selected areas representative of Thailand in such terms that estimates of vehicle performance could be made, (b) develop a method for interpreting, classifying, and mapping terrain factors from aerial photographs (air photos), and (c) utilize the field data collected and the air-photo interpretation method developed in preparing factor-family maps of six selected study areas in Thailand--Nakhon Sawan, Lop Buri, Chiang Mai, Pran Buri, Khon Kaen, and Chanthaburi (see fig. 1).

10. The specific purpose of the study reported herein was to delineate areas with equivalent trafficability characteristics on the basis of soil strength. This delineation was to be accomplished by the interpretation of maps and air photos, with control data supplied in the form of field and laboratory information. The delineated areas were to be classified for mapping, and an appropriate mapping symbology was to be developed. The maps compiled during this study are presented in Volume VIII of this report.

Scope

11. Areas were delineated and maps constructed for six selected study areas in Thailand. These study areas were chosen to represent a broad range of surface composition conditions. The methods and techniques used or developed to accomplish the classification and mapping were based on general terrain data obtained during several field surveys from 1962-1964. RCI, shear strength at zero normal load, and angle of internal friction were chosen for mapping in the six primary study areas. The actual delineation of areas was based on a reduced amount of specific field data taken from the study areas. The mapping classes developed herein were chosen and used without the benefit of any field verification and testing. The techniques for classifying and mapping surface

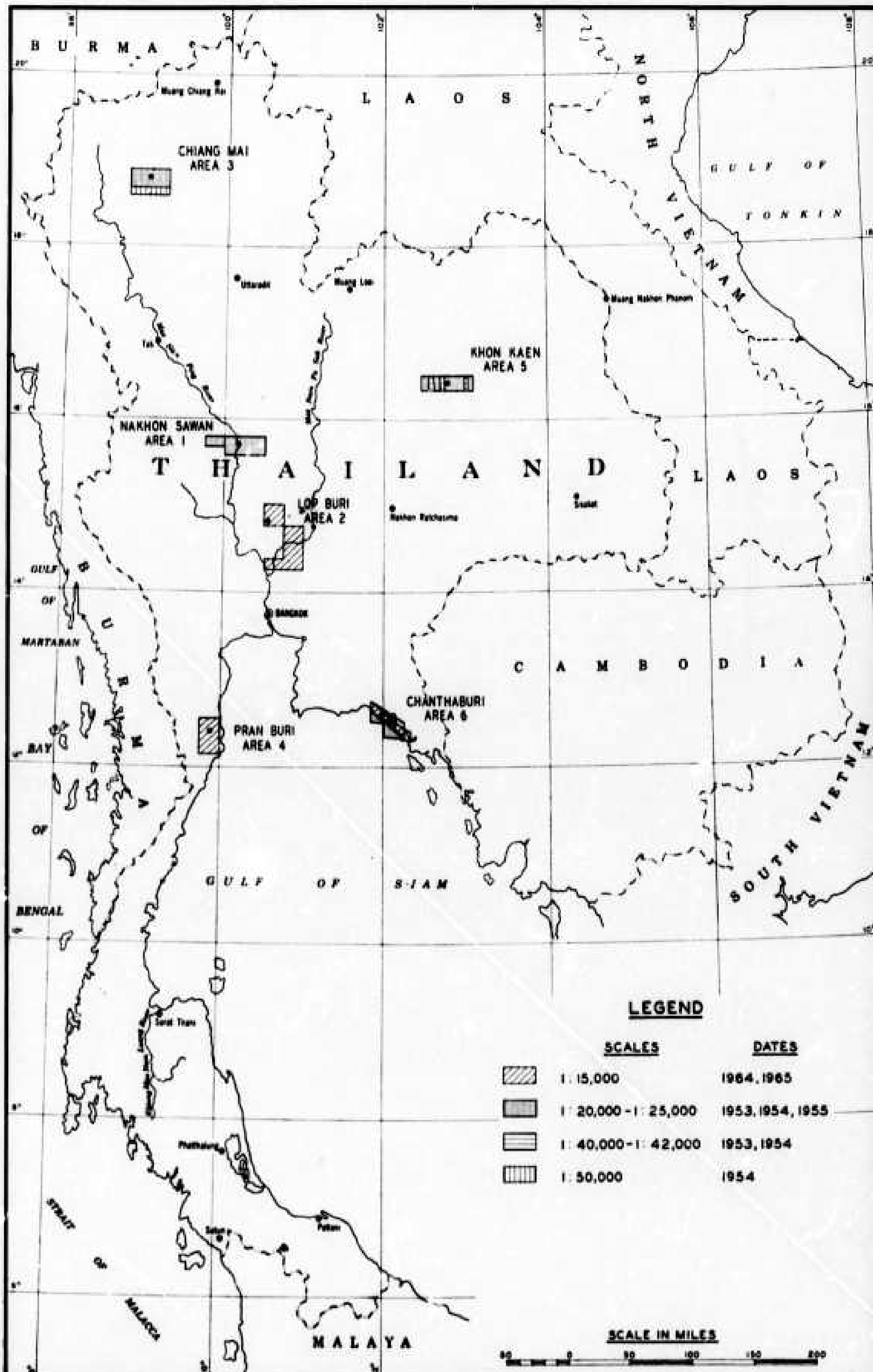


Fig. 1. Aerial photographic coverage of Thailand primary study areas

composition factors presented in this report are by no means being offered as final ones. The techniques and results are the best that could be developed from the particular data on hand.

PART II: DATA COLLECTION PROCEDURES

Site Selection

12. The selection of soil sites is largely dependent upon the purpose for which soils are being studied. A sample array chosen for an evaluation of the soils of an area for the construction of airfields would obviously be different from an array chosen for an evaluation of the soils of an area for construction of earth-fill dams. An array chosen for an analysis of soil characteristics for mobility purposes would be different from either of the above-mentioned arrays.

13. In this case, study sites were chosen to represent soil strength regime of each areally or positionally different soil type that was believed to be significant to ground mobility and that could be recognized on available air photos or maps. For example, in any area occupied by a particular soil type, topographic positions such as the tops, sides, and bottoms of hills were identified. Ideally, each site should have been visited several times in order to define the relations among soil moisture, seasonal precipitation or groundwater characteristics, and soil strength. However, multiple visits were seldom possible because of the severe time restrictions imposed by project scheduling.

14. Site selection was based on a combination of air-photo interpretation and ground reconnaissance. In those areas for which photography was available, a preliminary selection was made on the basis of differences in photo images that could be attributed to soil differences, or on the basis of topographic position in those areas where no obvious differences could be seen in the images. These sites were then checked on the ground by the team leader, who either confirmed or rejected them. Since the available photography was between 10 and 12 years old, many sites selected in this way were found to be redundant, the images having been controlled by minor vegetation differences or such things as variations in land use practices. When no air photos were available, sites were selected by on-the-ground reconnaissance, supplemented by low-altitude examination from the air where possible.

15. Because of the size of the primary study areas, a reasonable number of samples could be obtained only if travel time between sites could be held to a minimum. The effect of this constraint was to preclude examination of sites more than about 500 m from a passable road or trail or from a navigable stream. The general scarcity of passable roads and trails was such that nearly all sites were confined to narrow bands along roads. Obviously an important element in site selection was the ease with which examples of all soil types or moisture regimes could be located close to roads or trails. Because finding all soil types or moisture regimes close to roads was not always possible, obvious gaps in ground control did develop.

Location and Description of Sites

16. For interpretive and analytical purposes, it is usually necessary that the locations of soil sites be known very accurately, so that their positional relations to other soils, topographic features, or hydrologic features that might possibly affect their moisture regimes can be considered. For this reason, each site was meticulously located and marked on the best available map and/or air photo. Further, the soil site locations were described with such accuracy that they could be relocated at any time in the future. A topographic position data form (fig. 2) was prepared for all sites. Detailed instructions for filling out this form and supplementary instructions for preparing the profile sketch are given in another WES report.[6]

17. In most instances soils were sampled at such places or under such circumstances that vegetation, surface geometry, or other features of the site were obtained by the appropriate team for collecting factor-family data. In those instances where only soil samples were obtained, a certain amount of supplementary information was collected and recorded on a supplementary site data (soil moisture) form (fig. 3). Detailed instructions for filling out this form are presented in reference 6. Because the terms used in the form are mostly subjective, not all

TOPOGRAPHIC POSITION DATA FORM

Map reference: BAN PANG SOK, 5254 I, AMS Series L708, 1:50,000 Site No.: 27-SC

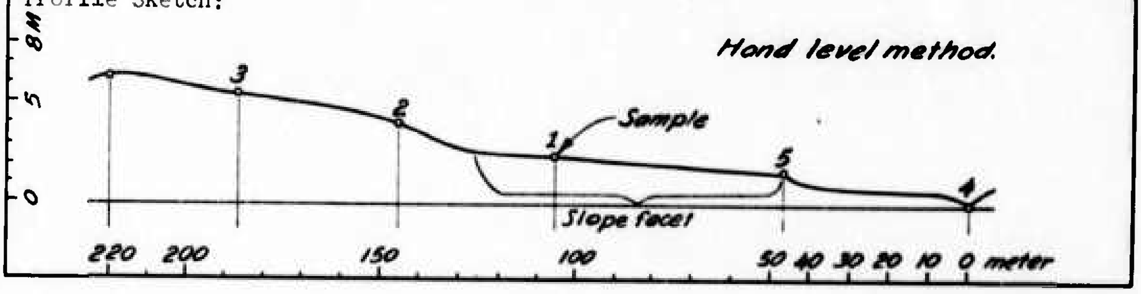
Geographic coordinates of site: 14°36'08"N, 101°27'47"E

Site elevation: 318 m Max topographic slope: <1° Slope azimuth: 233°

Unit measure: meters Sheet 1 of 3

Position No.	Vertical Distance, m		Horizontal Distance, m	Notes
	HI	Rod		
1	1.6	-	39.0	Open at sample site
2	1.6	-	42.0	
3	1.6	0.8	33.0	Top of topographic high
4	1.6	-	47.0	Topographic low
5	1.6	0.9	59.0	Final sight to sample site
	6.3		220.0	Totals

Profile Sketch:



Sampling Team: Grabau, Jirote

Fig. 2. Example of a topographic position data form used to describe soil site locations

SUPPLEMENTARY SITE DATA (SOIL MOISTURE)

Site No. 27-SC Location: 0.9 Km W of Ban Khanong Phra Nua

Sampling Team: Grabau, Jirote Page 2 of 3.

Land Use (Select as many as required to describe condition: circle appropriate terms.)

1. Not obviously used by man or domestic animals. Undisturbed.

2. Obviously used by man or domestic animals.

   a. Cropland currently in use (excluding hayfields, orchards, vineyards, tree plantations)

   b. Cropland currently lying fallow (excluding hayfields, orchards, vineyards, tree plantations)

   c. Area grazed by domestic animals

   d. Hayfields (not currently being grazed)

   e. Orchards, vineyards, tree plantations (type? ______________________)

   f. Lawns, recreation areas

   g. Logged, cut for fuel, newly cleared for slash-and-burn agriculture

Depth of water over soil surface (if any): None

Depth below surface of free water (if any): None

Depth to bedrock (if any): No rock to 75 cm.

Vegetation (select one, if possible. If a choice between two is difficult, indicate both.)

1.	Forest	5.	Tall scrub woodland	9.	Tall-grass prairie
2.	Woodland	6.	Tall scrub savanna	10.	Short-grass prairie
3.	Savanna	7.	Low scrub	11.	Barren
4.	Tall scrub forest	8.	Low scrub savanna		

Fig. 3. Supplementary site data (soil moisture) form

observers will interpret the items in the same way. However, this is not regarded as serious in this context.

Sampling Procedures

18. Detailed procedures for sampling are described in reference 6. The procedures used in collecting soil data at sites sampled specifically for this study are described briefly in the following paragraphs.

19. Four or more CI profiles were measured in 2.5-cm* vertical increments to a depth of 46 cm at each site. Remolding index tests were made on two samples each from the 0- to 15-cm and 15- to 30.5-cm layers. If the results of the tests of the two samples from each layer were not in close agreement, a third remolding index test was made, and the average of the three test results was used. Sheargraph measurements were made on the surface using a grouser to determine soil cohesion and apparent angle of internal friction. A flat, rubber-coated shear head was used to determine soil-to-rubber adhesion and rubber-to-soil friction angle.

20. At most sites soil samples were taken for laboratory analysis of moisture content, density, texture, Atterberg limits, and organic content. Samples for moisture and density were taken in 7.5-cm increments to a depth of 30.5 cm with a Hvorslev sampler. A bulk sample was taken from each of the 0- to 15-cm and 15- to 30.5-cm layers for the other laboratory analyses. Those laboratory data that were utilized in the final classification of surface composition features are given in Tables A1-A6. In some instances (see site 1-T-13, table A1) not all data specified by the instructions were taken, and in a few instances data were lost in the transfer from the field to the office; such gaps in data are indicated by dashes in tables A1-A6.

---

* All field measurements were made in British units since all instruments were calibrated in such units. Subsequent conversions to approximate metric equivalents were made in the office.

PART III: DATA SOURCES, REDUCTION, AND ANALYSIS

Data Sources

21. All available soil strength data were used to establish mapping units and ranges of variations of soil strength within each unit. Data collected at 882 sites for this and other MERS tasks, including the preliminary study,[7] were examined. Of the 882 sites, 579 yielded soil and site information pertinent to this study. These data are summarized in Appendix A. Only 367 of these sites were located within the limits of the study areas. Small-scale maps showing the location of these sites are also given in Appendix A.

22. Various soil survey reports of the Kingdom of Thailand[8,9] together with Pendleton's Thailand[10] provided very general background information on the characteristics, distribution, and general association pattern of soils. However, this information was of limited value because the distribution maps of the various sources are very small-scale and because no consistent relations between the mapped soil units and soil strength could be developed.

Data Reduction

23. The data presented in Appendix A provided the major source of information gathered from the study areas. Because of the large number of sites, these data were recorded or punch-coded along the margin of a special key-sort punch card to facilitate retrieval and statistical manipulation of the data. The key-sort punch card used is illustrated in fig. 4.

24. A modified binary coding system was used to enter data on the key-sort cards. The standard sequence of hole numbers (1-2-4-7) was modified to a system (1-2-4-8) that required less space. Despite the increased manipulation required for the modified system, it was preferred because more code bits per unit length of card perimeter could be used. To avoid the confusion of using both systems, the modified system was

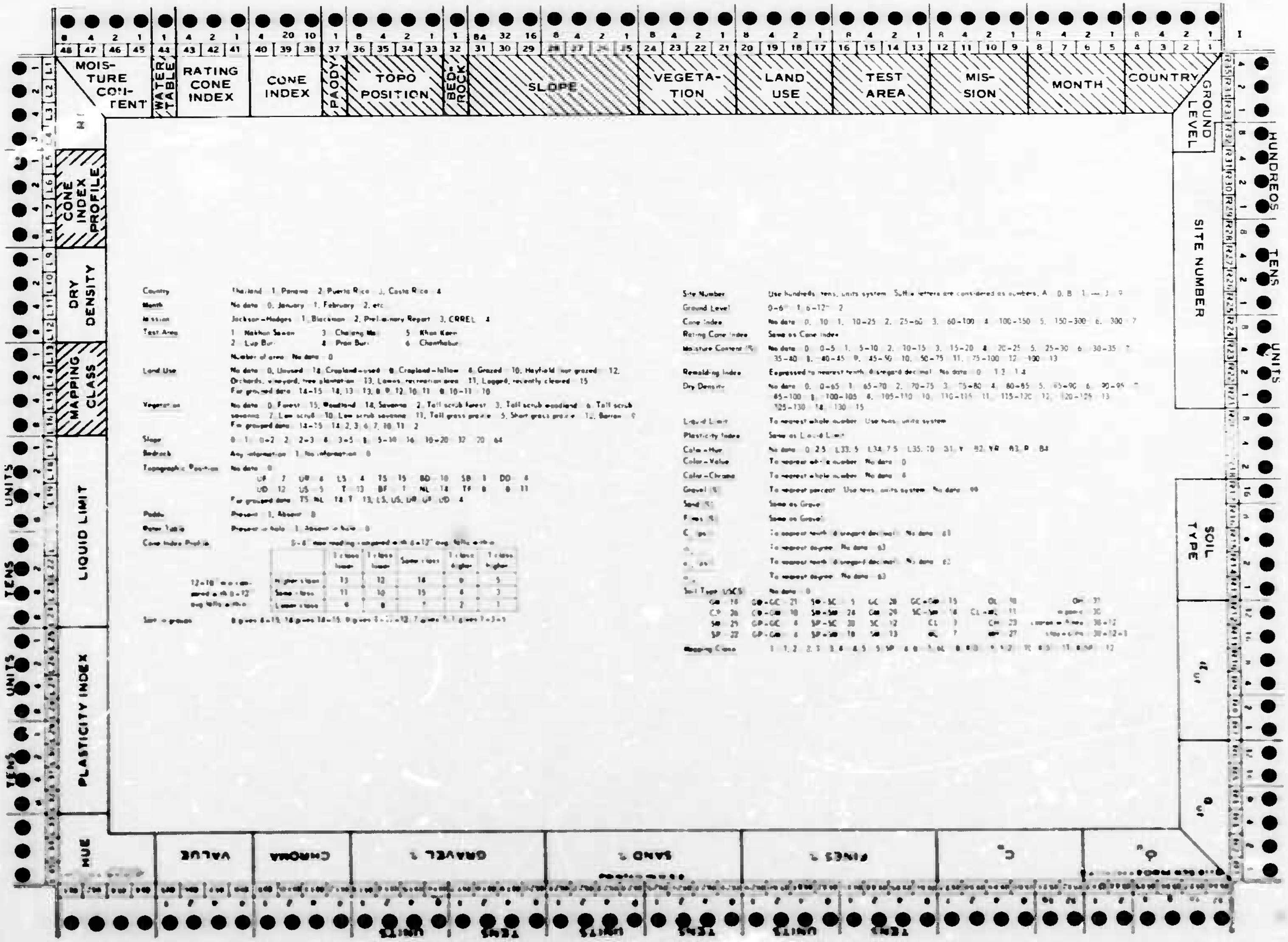


Fig. 4. Arrangement of surface composition data on key-sort punch card

applied to all parameters except one. Coding of color (hue) was accomplished by assigning a certain perimeter position to each hue. The coded card (fig. 4) can be read as follows:

Hole Combinations Punched	Code Numbers Represented
1	1
2	2
2-1	3
4	4
4-1	5
4-2	6
4-2-1	7
8	8
8-1	9
etc.	

Data Analysis and Selection of Factor Value Classes

25. The objective of the data analysis program was to develop a set of criteria for mapping the areal distributions of meaningful classes of soil strength. There were three important constraints. First, the soil strength classes had to be suitable as input to the analytical cross-country speed prediction model under development in a parallel research program being conducted under the MERS project. Second, the soil strength classes had to be based on recognizable air-photo patterns, because photo interpretation constituted the only practical method of extrapolating the detailed site data to the large areas encompassed by the study areas. This was obviously required for mapping purposes. Third, each soil strength class had to exhibit a distinctive soil strength regime in order to incorporate the obvious seasonal differences that were known to occur.

Soil mass strength

26. Straightforward statistical analyses of the field data for soil mass strength categories were not practical, because soil strength is a time-variable factor and the great majority of the field data represented one-time observations. Since soil mass strength regime is chiefly a function of soil type and soil moisture regime, the identification of

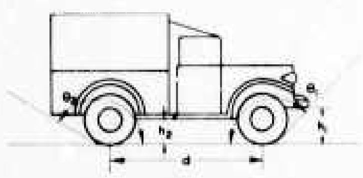
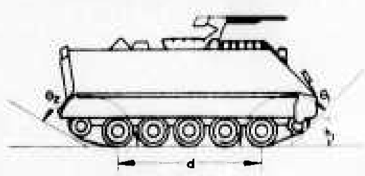
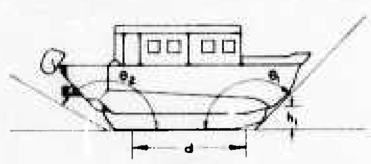
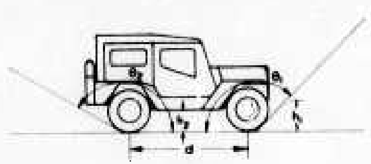
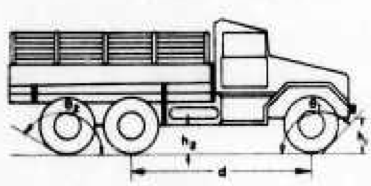
distinctive soil strength regimes resolved into a study of moisture content-soil type-soil strength relations. Therefore, emphasis was placed on relating strength to moisture content for different site characteristics.

27. The requirement that the soil mass strength classes be suitable as input to the speed prediction model could not be entirely met, because the model had not reached such a level of development that rigorous classes could be specified at the time when a decision on map units had to be made. Accordingly, soil mass strength value classes were initially specified on the basis of vehicle types that had been selected for MERS tests, since the range in their soil mass strength requirements was representative of that for most Army vehicles expected to operate off roads at least sometimes. Some of the characteristics of these vehicles that are pertinent to their cross-country performance are tabulated in fig. 5. The vehicle cone index (VCI) requirement, or the minimum soil strength in terms of RCI that will allow a vehicle to complete one or 50 passes in a straight-line path, is given in the following tabulation for the vehicles considered in this study.

Vehicle	VCI Required for 50 Passes	VCI Required for 1 Pass*
M29C	25	13
M151	60	30
M37	65	33
M113	47	24
M35A1	69	35

* Estimated at 50 percent of the 50-pass requirement.

28. Consideration of the VCI_{50} and VCI_1 values of the vehicles suggested that useful classes would result if the divisions were made at RCI values of approximately 10, 25, 50, and 70, which would result in five mapping classes. The division at 10 RCI was introduced in order to define areas of extremely soft soil, in anticipation of the possible availability of very low-contact-pressure vehicles. The map classes used finally were: <10, 10-25, >25-60, >60-100, and >100 as explained in paragraph 40.

	VCI 50	h_1* CM	h_2** CM	θ_1† DEG	θ_2†† DEG	d‡ CM	GRADE-ABILITY % DEG	WEIGHT KG
 M37 3/4-TON CARGO TRUCK	65	53	41	142	148	284	68 34.2	3180
 M113 ARMORED PERSONNEL CARRIER	47	58	--	110	140	267	60 31	9980
 M29C AMPHIBIOUS CARGO CARRIER	25	34	--	134.4	151	198	100 45	2720
 M151 1/4-TON UTILITY TRUCK	60	36	26	112	143	216	60 31	1031
 M35A1 2-1/2-TON CARGO TRUCK	69	84	53	142	140	330	64 32.6	8840

NOTE: ALL DIMENSIONS PRESENTED IN THIS FIGURE WERE TAKEN DIRECTLY FROM THE TEST VEHICLES.[11]

GRADEABILITY DATA TAKEN FROM ORDNANCE CORPS EQUIPMENT DATA SHEETS.[12]

*h_1 = HEIGHT FROM WHICH VEHICLE APPROACH ANGLE IS TAKEN

**h_2 = PROFILE HEIGHT BETWEEN WHEELS OR TRACKS

†θ_1 = VEHICLE APPROACH ANGLE
††θ_2 = VEHICLE DEPARTURE ANGLE
NOTE THAT ANGLES ARE MEASURED AS OBTUSE ANGLES; TO CONVERT TO PRACTICE AS GIVEN IN TM 9-500, USE: $180° - \theta$.

‡d = WHEEL BASE (NOTE DIAGRAM ABOVE FOR METHOD OF DETERMINATION FOR M35A1)

Fig. 5. Vehicle characteristics related to vertical obstacle crossing capability

29. When the site data were sorted by USCS soil types, no recognizable pattern of RCI values was revealed. Plotting RCI versus moisture content revealed a family of curves that corresponded to the USCS in a general way (fig. 6). Too much scatter was present to distinguish specific classes, but broad groupings occupied recognizably different parts of the chart. It was therefore possible to establish the following preliminary classification of soils: (a) coarse-grained soils with fines, low plasticity or nonplastic; (b) fine-grained soils, low plasticity; (c) fine-grained soils, high plasticity; (d) fine-grained soils, high plasticity, high organic content; and (e) soils associated with shallow bedrock or hard laterite (see fig. 6).

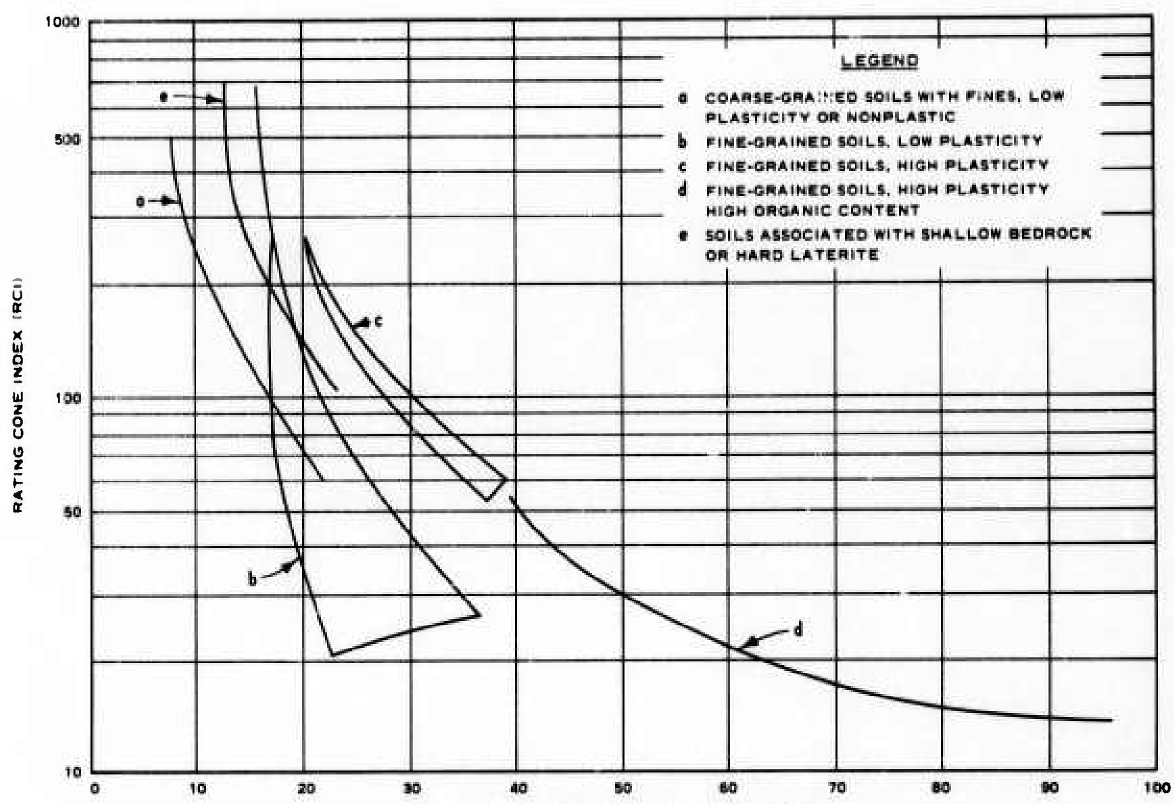


Fig. 6. Characteristic relations of rating cone index to moisture contents for preliminary soil classification

30. Soils occurring in (d) above fell on the same curve as those described in (c), but fell in a different range (higher moisture content and lower RCI) and were found to be associated with tidal flats. Soils

described in (e) were strong regardless of texture and topographic position. No soils occurring in (c) exhibited high moisture contents. Scatter of the RCI-moisture content plots* did not permit distinction of individual USCS soil types but did show general differences between certain associations of types. Soils along curve a in fig. 6 were mostly SM and SC; soils on curve b were mostly ML and CL; soils on curve c were mostly MH and CH; and those on curve d consisted primarily of CH, OH, and MH soils. The MH, CH, and OH soils distinguish the soft tidal flat deposits from the much stronger dry land soils. The USCS class of the soils associated with shallow bedrock or hard laterite was not relevant.

Soil surface strength

31. Soil mass strength is not the only soil factor that affects vehicle mobility. It is known, both from practical experience and from preliminary tests, that the slipperiness of a surface is also important, especially for a vehicle climbing slopes or crossing vertical obstacles. In an attempt to provide data for the evaluation of this factor, sheargraph measurements were included in the standard data collection procedure.

32. Upon completion of the investigation of soil mass strength, the soil surface strength as measured by the sheargraph was examined in order to establish appropriate class limits for mapping purposes. Soil surface strength is also time-variable. The relations between sheargraph values and moisture content in the surface layer of the soils in the six study areas were not known at the time of this study. However, previous experiments on tropical soils had demonstrated a general relation between shear strength at zero normal load a_{ur} and moisture content.[14]

33. In the absence of reliable knowledge of the effects of soil surface strength on vehicle performance, a completely arbitrary, but reasonable, division of the data into classes for the preliminary classification was used. The class units were chosen as illustrated in fig. 7. Both the shear strength at zero normal load a_{ur} and the angle of friction

* Specific relations among cone index, rating cone index, and soil moisture are given in detail in a previous WES report.[13]

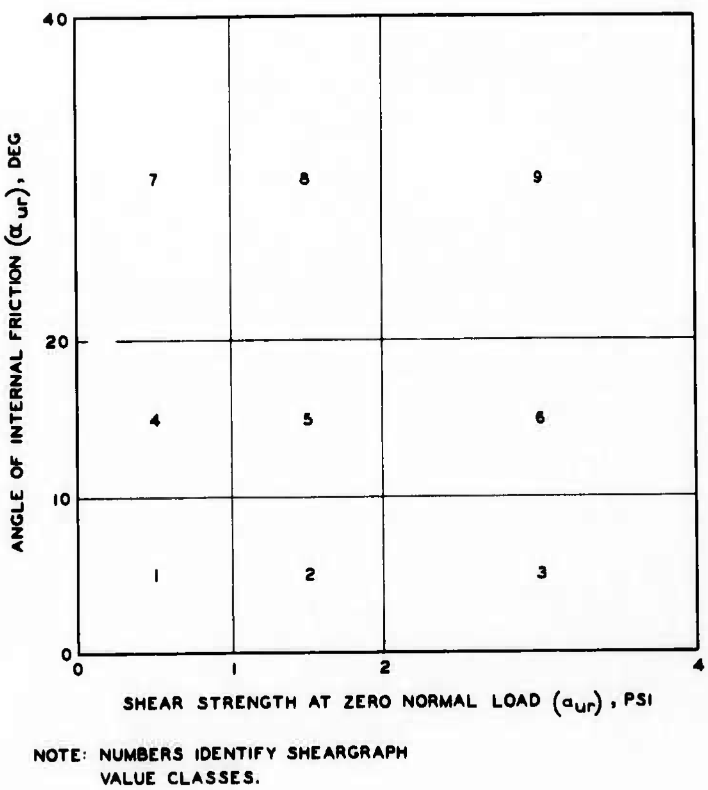


Fig. 7 Soil surface strength classes

α_{ur} were divided into three unequal classes, resulting in nine distinctive classes, each of which was given an arbitrary code number, as indicated in fig. 7.

PART IV: INTERPRETATION AND MAPPING TECHNIQUES

Development of Photo-Interpretation Keys

34. It is difficult to describe in detail the analytical procedures or the developmental steps involved in the derivation of the photo-interpretation keys and the final classes for use as map units. The actual process was by no means simple and straightforward; instead, it was a process of continual compromise between the requirements of the analytical speed prediction model, the available ground data, and the recognizability of images on the air photos. The requirements of the analytical model would have best been served by very small class intervals for all three selected factors (i.e. RCI, shear strength at zero normal load, and angle of internal friction). However, such class intervals could not be made practical, chiefly because there was no hope of being able to recognize them reliably by photo interpretation. The result was a compromise between the broad classes demanded by the photo interpreters and the narrow classes desired by the engineers concerned with the analytical performance prediction model. A greatly simplified diagram of the process is given in fig. 8. The point of departure was the five general classes derived from the diagram illustrated in fig. 6, which identifies RCI-moisture content relations and relates them in a crude way with USCS soil types.

Topographic position

35. Within each of the above-mentioned broad groupings of soils, sites were sorted according to topographic position as contained in the site descriptions. The result of this process is indicated in the topographic position column in fig. 8. A few topographic positions, such as natural levees, tended to be associated with high RCI values regardless of other conditions. Others, such as tidal flats, exhibited consistently low RCI values.

Position with respect to water

36. The ease of drainage and the proximity to sources of water also were found to be significant criteria for classification. Therefore,

Soil Classes		Topographic Position	Position with Respect to Water	Land Use	Map Unit
From Fig. 6	USCS Types				
a	SM, SC	Broad, rolling upland	100 m from surface water	Not signif- icant	11
b	CL, ML, some SM	Alluvial plains	Intermediate water table	Not signif- icant	4
			Shallow water table	Not signif- icant	2
		Drainageways and lower side slopes	Rapid changes in water table in short distances	Not signif- icant	5
			Shallow water table	Not signif- icant	3
	CL, SM, SP	Natural levees and village platforms	Near open water	Villages	13
c	MH, ML, CL	Broad alluvial plains	Intermediate water table	Not signif- icant	9
	CH, some CL, MH	Flat, uniform alluvial plains	Shallow water table	Tilled	8
				Untilled	10
			Water table almost at surface	Tilled	6
				Untilled	7
d	CH, OH, MH	Tidal flats	Periodic inundation	Not signif- icant	1
e	Not rele- vant	Hills, mountains, rock terraces	Deep water table	Not signif- icant	12
		Flat to rolling	Deep to shallow water table in short distances	Tilled	14
				Untilled	15

Fig. 8. Development of photo-interpretation criteria (generalized)

the next stratification process tended to be based on water availability. In this category, slope appeared to be the dominant property for identification of fine-grained soils, whereas elevation above surface drainage level seemed to be the major determinant for coarse-grained soils. Although topographic position implies a general correlation with water table conditions, special classification was reserved for those areas where the water table remains so near the surface that the soils do not dry out even in the dry season.

Land use

37. When attempts were made to include recognition criteria for soil surface strength (i.e. sheargraph parameters), the soil-topographic classes already established for soil mass strength (RCI) had to be accepted, chiefly because no applicable field moisture data were available on the surface layer of soil. Within each soil-topographic position class already established, card sorts were run using other site factors as the basis of stratification. The only site descriptor found to correlate with soil surface strength was land use. In highly plastic soils, regularly tilled areas showed values different from those of untilled areas for the soil surface strength parameters. This stratification is indicated by the land use column in fig. 8. These correlations were valid only for the rubber-to-soil sheargraph measurements. Because the data taken with a grousered foot did not correlate with any site descriptor, they were discarded. The map unit column in fig. 8 shows the mapping class units into which each set of site descriptors was placed.

38. Land use also appears to be a significant factor in village areas; RCI values higher than those suggested by soil type or topographic position were observed in such locations. This probably is a result of artificial compaction of the soil and man-made drainage control. The land use effects of village platforms and soil tillage are the only ones reflected in the final classification. As an indicator of natural conditions, however, land use was extensively used in photo interpretation.

Special areas

39. Areas of bedrock and hard laterite at shallow depths where high strength prevailed regardless of soil type or topographic position were

often recognized from distinctive vegetation patterns or field configurations. Areas of consistently low RCI values such as swamps, marshes, sloughs, and tidal flats were recognized from certain consistencies in tone, texture, and topographic position.

Refinement of classification criteria

40. The air photos and topographic maps of data sites were constantly reexamined as new classification criteria were developed and preliminary classifications of site characteristics were erected. Every device of the interpretive art was used in the process of building up the recognition capability. The final product of the process is summarized in table 1. It should be noted that one result of the succession of compromises was alteration of the RCI classes that had been tentatively selected at the beginning of the study. The original classes, as described in paragraph 28, could not be reliably identified by photo interpretation. They were accordingly changed to the following: <10, 10-25, >25-60, >60-100, and >100. These new classes, though slightly less desirable for input into the analytical model than the old classes, were still acceptable.

Soil surface strength

41. A considerably more refined concept of soil surface strength (or sheargraph value) classes was also evolved after study of the data from Thailand, even though the original class intervals (fig. 7) remained unchanged. It was noted that maximum soil shear strength at zero normal load rarely occurred at maximum or minimum moisture content. It was also noted that all soils in a given surface composition class (table 1) exhibited similar sheargraph values. The relations that were eventually established as characterizing the sheargraph values of each class are illustrated in fig. 9.

42. The sheargraph categories in fig. 9 are constructed in the same way as those in fig. 7. The hatched areas indicate the intervals (i.e. the soil surface strength classes, see fig. 7) in which most of the sheargraph values fell in those samples at the indicated moisture content in the recognition class. For example, in surface composition class 1 (see table 1), most of the sheargraph values fell in sheargraph value class 1 when the soils were sampled at or near their maximum moisture content, and in sheargraph value class 5 when the soils were at or near minimum

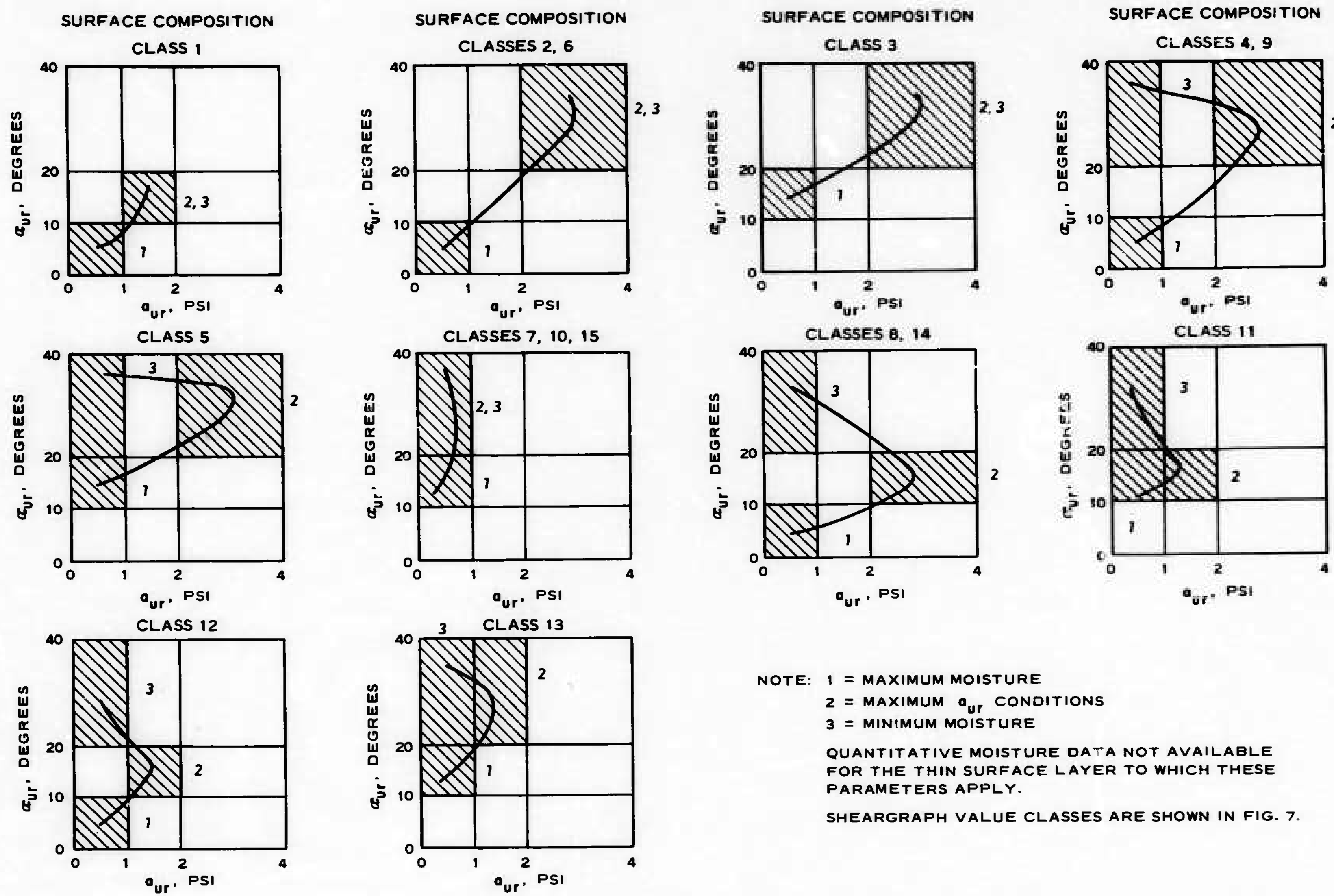


Fig. 9. Categorization of soil surface strength-moisture condition relations

moisture content and at that moisture content that produced the maximum a_{ur} value. The curves on the diagrams in fig. 9 indicate the estimated central tendency of the field data. These diagrams make it possible to associate each surface composition class with a sheargraph value class regime.

Application of recognition criteria

43. The sequence in which recognition criteria were applied in the actual interpretation process of surface composition classes (table 1) was as follows:

a. The first step separated the broad, low, alluvial plains; the broad, rounded, upland terraces; and the strong relief features formed by bedrock. The bedrock relief features were assigned to class 12 without further subdivision.

b. In the upland terraces, poorly drained valley bottoms and lower slopes were separated from the well drained upper slopes, using the criterion that well drained areas must be separated from surface drainage features by a slope of at least 2 percent over a distance of at least 100 m. The poorly drained areas were assigned to class 5, the well drained areas to class 11.

c. In the broad alluvial plains, the dominant relief features were natural levees and village platforms; these were delineated as class 13. Most of the remaining areas consisted of low-lying paddies, in which distinction on the basis of soil textures was possible. Sandy soils were recognized from undulating surfaces reflected in mottled photo tones, numerous trees, and close association with the broad upland terraces of class 11; these soils were assigned to class 5. Fine-grained soils of low plasticity were characterized by numerous trees and termite mounds, faint mottling, and distribution along the margins of the plain or adjacent to natural levees. These were mapped as class 4.

d. Although distinct relief features comparable to natural levees were lacking in these soils, in places they exhibited a rolling surface with slopes of more than 2 percent. Field data indicated that 2 percent slope was critical to the quality of drainage in these soils, and accordingly, areas exhibiting slopes steeper than 2 percent were distinguished as class 9.

e. Fine-grained soils of high plasticity occurred in the broad, low central parts of the alluvial plains and in small pockets and depressions elsewhere; these showed highly uniform tones, almost complete absence of trees and termite mounds, and relatively large, regular field patterns. The tilled areas of these soils were mapped as class 8, the major untilled areas as class 10; this distinction was made

because of an apparent effect of regular tilling on surface strength parameters in these highly plastic soils.

f. Swamps, marshes, and undrained depressions could be recognized from dark tones or standing water in photographs taken during the dry season. They were distinguished from all the other classes as areas in which the water table was sufficiently near the surface to prevent seasonal drying. These areas were mapped as class 2, 3, 6, or 7, depending on the primary class (4, 5, 8, or 10, respectively) with which they were associated.

g. Two types of complexes occurred in the alluvial plains--areas underlain at a shallow depth by hard laterite and areas underlain at a shallow depth by limestone. The lateritic areas were characterized by distinctive mottled dark tones combined with a thin and patchy pattern of cultivation. The limestone areas showed distinctive karst development with numerous sinkholes and lack of integrated drainage. Because of the unpredictable variations in depth of soil, both kinds of areas showed highly variable soil strengths within short distances. The tilled portions of both were mapped as class 14, the untilled portions as class 15.

h. The final component of the alluvial plains consisted of highly organic portions of the tidal flats and coastal depressions of the Pran Buri and Chanthaburi areas. These were without visible relief and extremely dark-toned. They were mapped as class 1.

44. Photographs 1-4 are stereopairs of vertical aerial photographs where 9 of the 15 surface composition classes have been identified through the procedure described above. Photographs 5-14 are ground views of selected sample sites with the soil consistency classes indicated.

Map Preparation

45. With the completion of the photo-interpretation keys, it became possible to compile a legend for the soil factor-family maps. The 15 recognizable classes of combinations of photo features, as defined in table 1, were numbered consecutively, and the ranges of soil strength associated with each were tabulated, as illustrated in table 2. Thus, the column at the left in table 2 (headed "Map Unit") is identical with the column at the left in table 1 (headed "Class"); map unit 4 is equivalent to class 4, etc.

46. Mapping was accomplished by stereoscopic examination of air photos. The scales of the air-photo coverage within the mapped areas are shown in fig. 1. Map boundaries were drawn using the predetermined photo-interpretation criteria shown in table 1. As mapping progressed, each field study site was identified as to its mapping class, and data on strength values and moisture conditions were entered on charts for that class (see fig. 10). This site identification was made according to photo-interpretation criteria rather than consideration of the data actually obtained. The latter would have involved map correction in only insignificant small areas surrounding the data point, whereas the method used gave an objective appraisal of map reliability and degree of variation within a mappable unit. The predetermined photo-interpretation criteria were consistently followed. Therefore, the spread of values for field data within any one class is fairly indicative of the range and pattern of strength variations with moisture as shown in table 2 and figs. 9 and 11. The overlapping of several USCS soil types in the classes shown in table 1 as well as the degree of scatter of the RCI-moisture content plots (fig. 10) is an indication of the less-than-perfect nature of the photo-interpretation criteria. The classification techniques and map delineations are the best that could be developed from the data available, but are not necessarily those that would result if additional data had been available. Because of the somewhat crude and overlapping boundaries of the photo-interpretation criteria, the soil strength data presented are less useful for predicting individual vehicle performance than for selecting vehicle types for strategic planning and development of vehicle design.

47. It should be noted that all the soils of a given region rarely, if ever, exhibit the same extreme of moisture conditions simultaneously. This is particularly notable in the wet season when soils may range from saturated to dry within short distances merely as a result of local rainfall conditions. A rough approximation of this variability is indicated in figs. 12 and 13, which show the frequency distribution of RCI values actually observed during a major wet season that lasts from mid-June to mid-December. Only those classes from which the data base was large enough to be of likely significance are charted. It should also be noted and

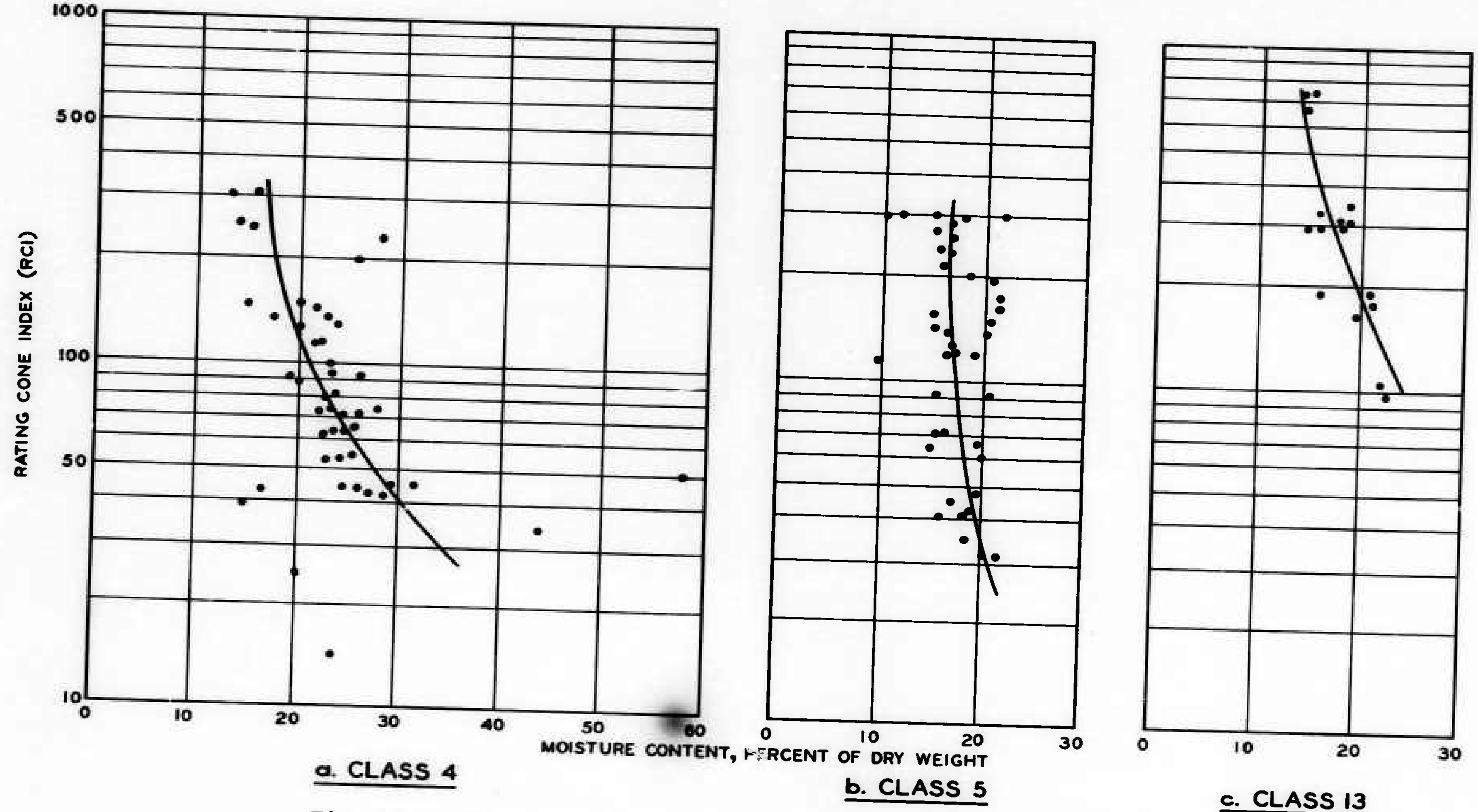


Fig. 10. Rating cone index versus moisture content for surface composition classes 4, 5, and 13

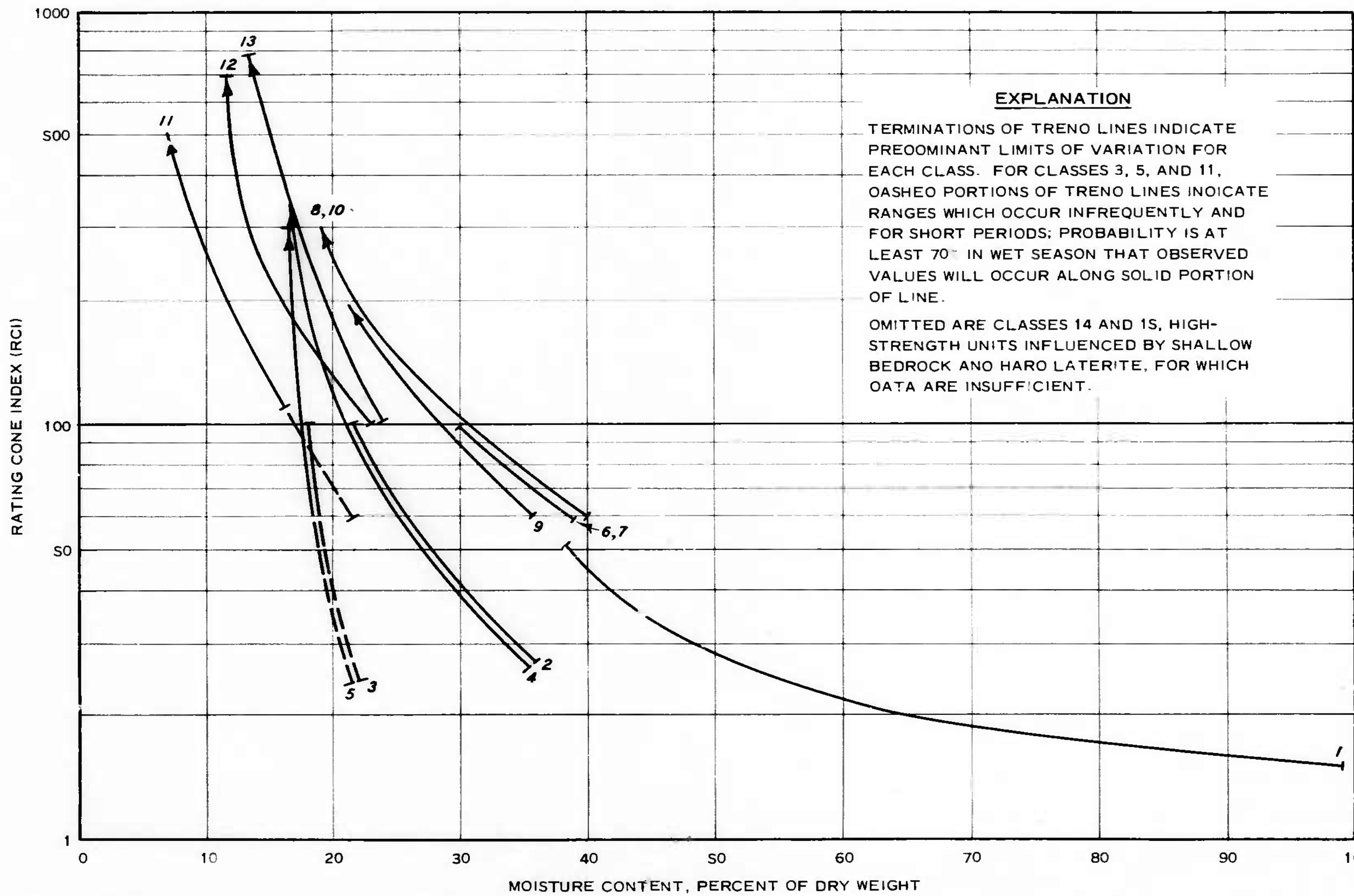


Fig. 11. Characteristic relations of rating cone index to moisture contents for surface composition classes

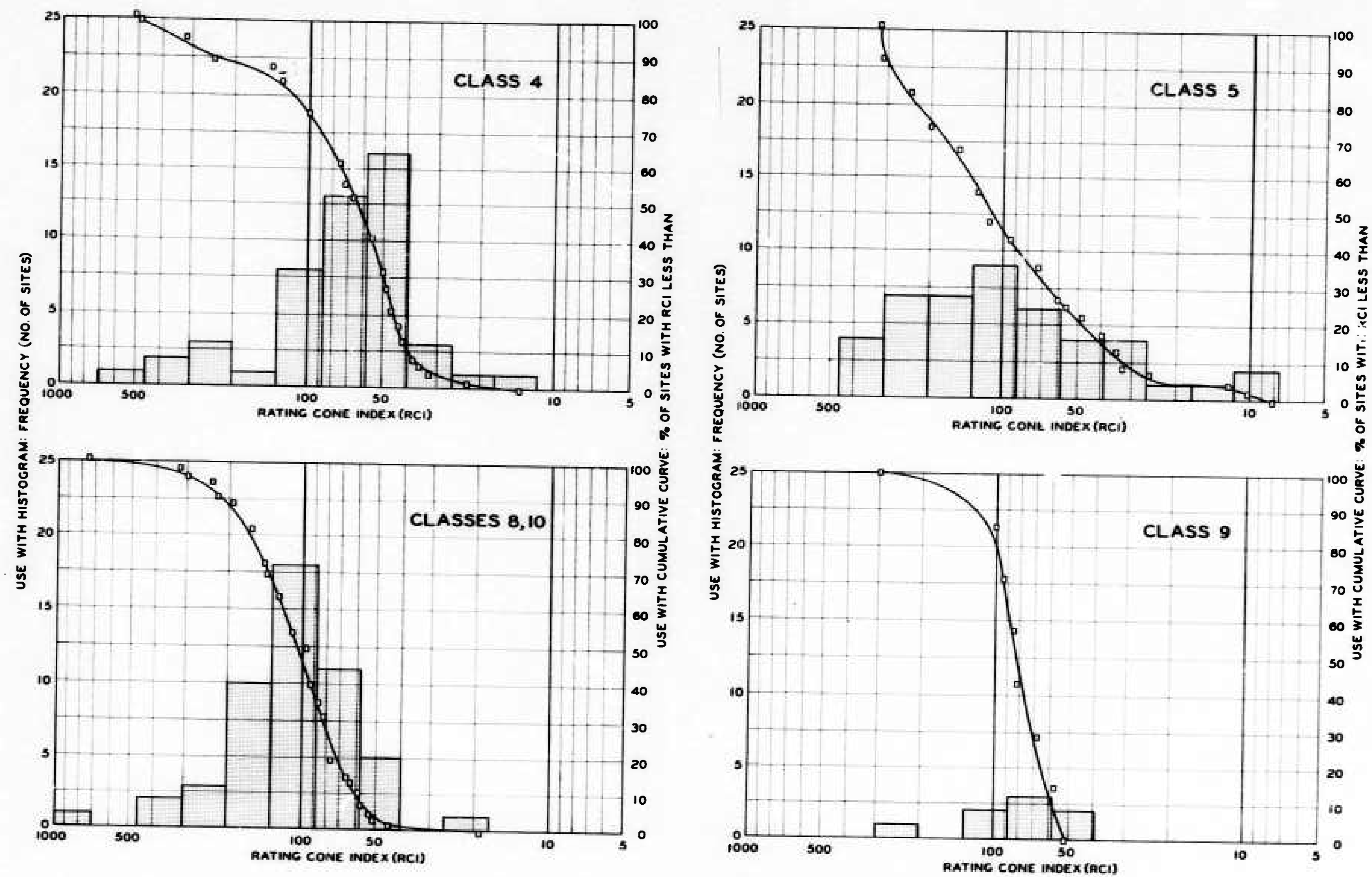


Fig. 12. Frequency of observed values for rating cone index (15- to 13-cm layer) from mid-June through mid-December from mapping classes 4, 5, 8, 10, and 9

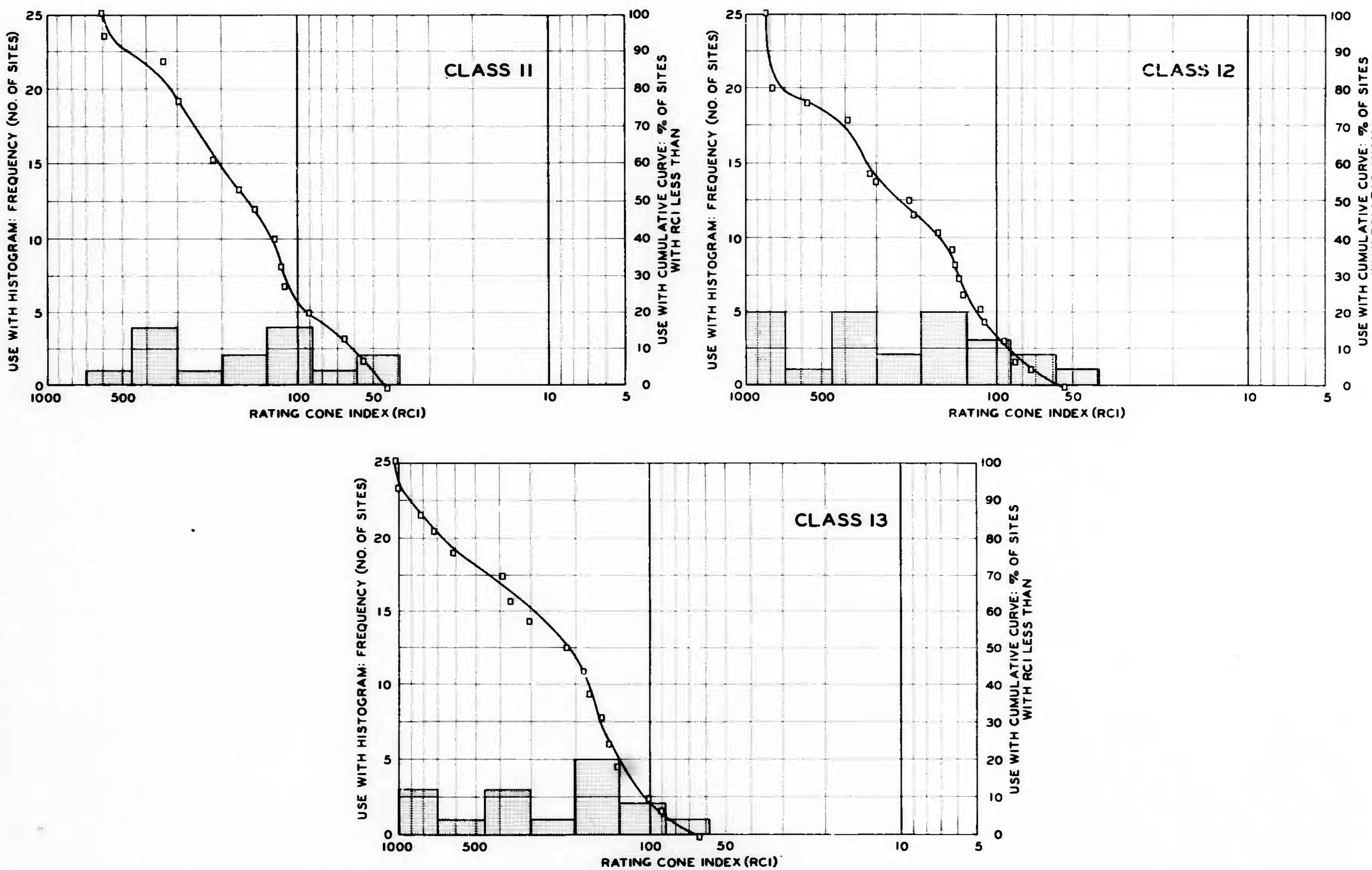


Fig. 13. Frequency of observed values for rating cone index (15- to 30-cm layer) from mid-June through mid-December for mapping classes 11, 12, and 13

emphasized that the frequency distributions illustrated in figs. 12 and 13 are derived from site data, and that the sites were not randomly distributed within the study areas, or distributed in proportion to the area of occurrence of the condition being sampled. Thus, no interpretation of areal extent or of temporal frequency should be made on the basis of these diagrams; they are intended only to indicate the total range of variation and the distribution of values within the sample population.

48. Factor-family maps were prepared by transferring class boundaries from air photos to the maps. Because the map scale (1:50,000) was usually smaller than the scale of the air photos, the data had to be reduced when the area outlines were transferred from the air photos to the maps.

49. The surface composition factor-family maps of the six study areas are presented in Volume VIII of this report series. These maps are on base sheets at a scale of 1:50,000 taken from the Army Map Service (AMS) Series L708. The limits of these maps do not, in all instances, coincide with those of the AMS sheets because new base sheets were made, where needed, to reduce the number of partially mapped sheets (see fig. 14). These limit changes were in most cases a matter of shifting the latitude or longitude 5 or 10 deg from those of the AMS sheets. Preparation of new base sheets resulted in a reduction of the total number of base sheets covering the six study areas from 32 to 25.

50. A portion of a surface composition factor-family map of the Lop Buri study area (sheet LB III) and the accompanying legend are shown in fig. 15. Since only a portion of the map is shown, all combinations included in the legend do not occur on the map segment.

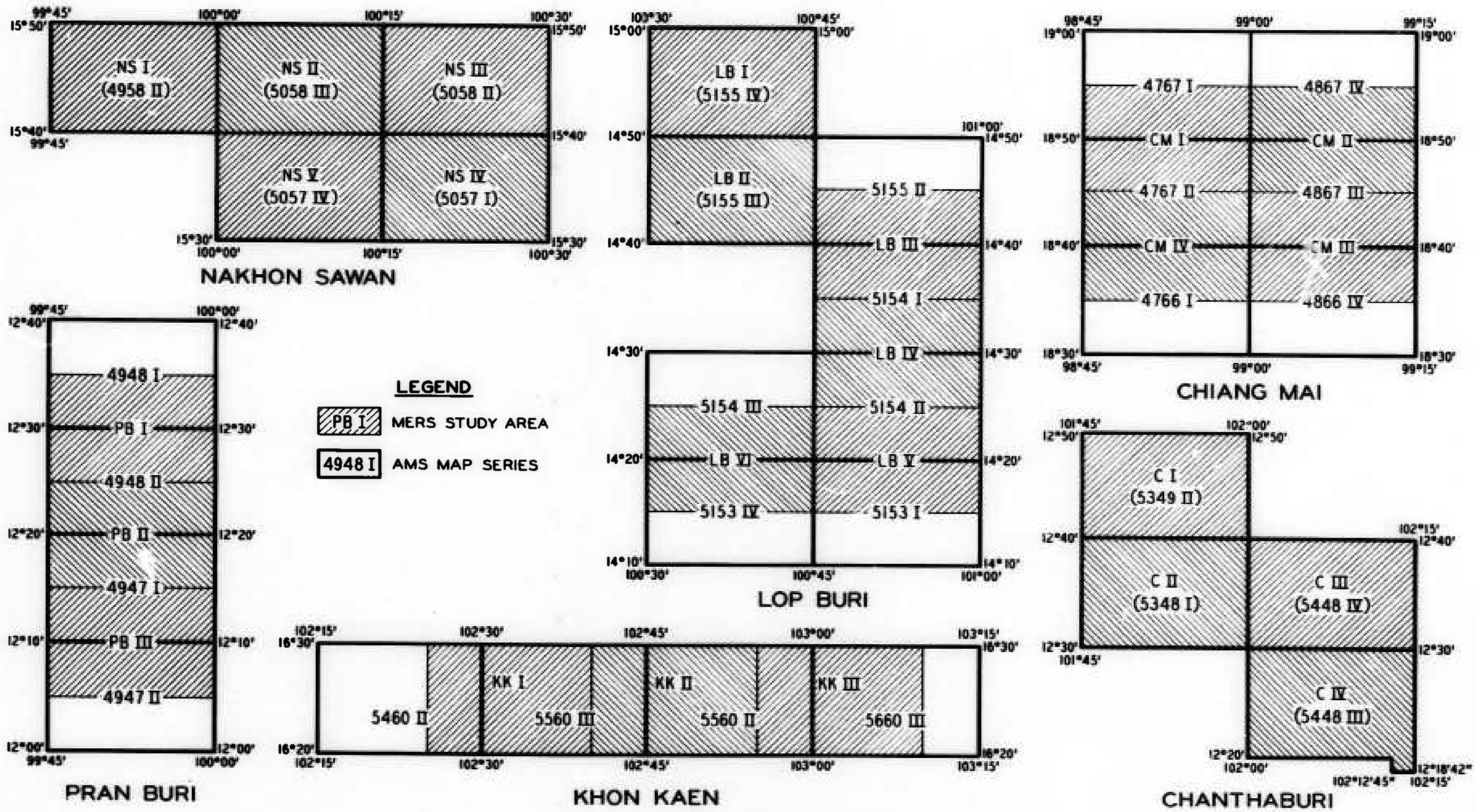


Fig. 14. Relation of MERS and AMS quadrangles

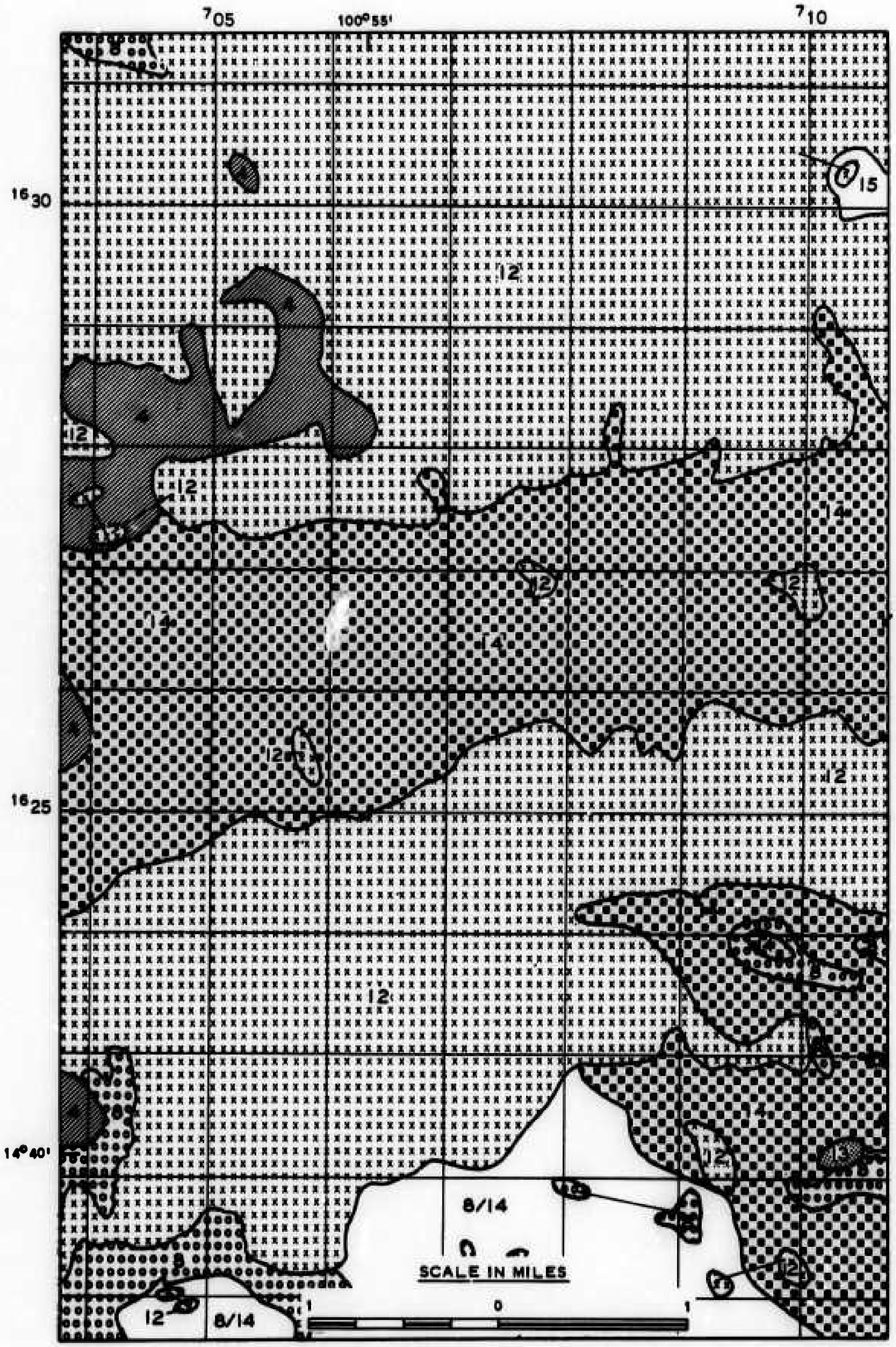


Fig. 15. Surface composition factor-family map of a portion of MERS sheet LB III in the Lop Buri study area (sheet 1 of 2)

LEGEND

Unit	Soil Mass Strength: Maximum Moisture RCI	Soil Mass Strength: Minimum Moisture RCI	Soil Surface Strength: Maximum Moisture a_{ur} psi	Maximum Moisture a_{ur} kg/cm^2	Maximum Moisture α_{ur} deg	Minimum Moisture a_{ur} psi	Minimum Moisture a_{ur} kg/cm^2	Minimum Moisture α_{ur} deg	Conditions where maximum a_{ur} occurs: a_{ur} psi	Conditions where maximum a_{ur} occurs: a_{ur} kg/cm^2	Conditions where maximum a_{ur} occurs: α_{ur} deg
1	10-25	>25-60	0-1	0-0.07	0-10	1-2	0.07-0.14	10-20	Minimum moisture conditions		
2	>25-60	>60-100	0-1	0-0.07	0-10	2-4	0.14-0.28	20-40	Minimum moisture conditions		
3	>25-60*	>60-100	0-1	0-0.07	10-20	2-4	0.14-0.28	20-40	Minimum moisture conditions		
4	>25-60	>100	0-1	0-0.07	0-10	0-1	0-0.07	20-40	2-4	0.14-0.28	20-40
5	>25-60*	>100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	2-4	0.14-0.28	20-40
6	>60-100	>60-100	0-1	0-0.07	0-10	2-4	0.14-0.28	20-40	Minimum moisture conditions		
7	>60-100	>60-100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	Minimum moisture conditions		
8	>60-100	>100	0-1	0-0.07	0-10	0-1	0-0.07	20-40	2-4	0.14-0.28	10-20
9	>60-100	>100	0-1	0-0.07	0-10	0-1	0-0.07	20-40	2-4	0.14-0.28	20-40
10	>60-100	>100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	Minimum moisture conditions		
11	>60-100*	>100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	1-2	0.07-0.14	10-20
12	>100	>100	0-1	0-0.07	0-10	0-1	0-0.07	20-40	1-2	0.07-0.14	10-20
13	>100	>100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	1-2	0.07-0.14	20-40
14	Complex of 60-100 and >100	>100	0-1	0-0.07	0-10	0-1	0-0.07	20-40	2-4	0.14-0.28	10-20
15	Complex of 60-100 and >100	>100	0-1	0-0.07	10-20	0-1	0-0.07	20-40	Minimum moisture conditions		

Note: Blank areas are water bodies.

a_{ur} Shear strength at zero normal load.

α_{ur} Angle of internal friction.

* Maximum moisture has less than 30 percent probability of occurrence during the wet season. Lowest strengths commonly observed are >60-100 for Units 3 and 5, more than 100 for Unit 11.

Units do not occur on this map.

Fig. 15. (sheet 2 of 2)

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

51. Soils of the study areas have been mapped according to the classes shown in table 1, and the results are shown in 25 plates in Volume VIII. The criteria used in establishing these classes were (a) that each class must be identifiable through use of air-photo techniques, and (b) that each class must exhibit a distinctive pattern of strength associated with variation in moisture content.

52. It is concluded that:

<u>a</u>. The moisture content-soil type-soil strength relations are the most valuable in developing a classification system for mapping purposes (paragraph 26).

<u>b</u>. Because moisture content is time-variable, the one-time observations used to a large extent in this study offer only a good indication of the soil strength-moisture content relations that exist. Neither these relations nor the classification system derived from them is to be construed as final, but only as approximations (paragraph 29).

<u>c</u>. The soil surface strength has a modifying influence on the classification system developed from the soil moisture relations. In certain soil types the tillage of the soil proved to be significant (paragraph 37).

<u>d</u>. Maximum shear strength at zero normal load rarely occurs at the maximum or minimum soil moisture content for a given soil (paragraph 41).

<u>e</u>. A compromise between the desired degree of mapping class refinement and that dictated by the photo-interpretation criteria is necessary because of the nature of the field data (paragraphs 34 and 40).

<u>f</u>. The significant photo-interpretation criteria are topographic position, drainage, land use, and vegetation (paragraphs 35, 36, and 37).

<u>g</u>. The mapping program delineates areas with roughly equivalent trafficability characteristics based on soil strength. When sample site data are extrapolated to unsampled areas, the degree of mapping refinement is, of necessity, only fair to low (paragraph 46).

<u>h</u>. The greatest variation in soil strength and therefore the greatest trafficability problems occur under maximum soil moisture conditions. Conversely, few trafficability

problems resulting from insufficient soil strength occur under minimum soil moisture conditions. Areas exhibiting exception to this generalization are marshes, swamps, and other areas with an extremely high water table where moisture contents are high all year (table 2).

Recommendations

53. It is recommended that:

<u>a</u>. Additional studies be conducted on the use of air-photo identification techniques in classifying soil strength conditions. This approach is believed to be basically sound; however, more field verifications of predicted values will help to determine the reliability of this approach. Similarly, an increase in the number of strength measurements at field sample sites is needed where the variance of the maximum and minimum RCI values used to obtain the RCI spreads across several class ranges. Additional measurements may tend to group values within narrow limits.

<u>b</u>. The feasibility of establishing a more comprehensive breakdown of moisture conditions should be studied. Even the maximum and minimum moisture conditions used in this study are not always adequate to describe soil strength. For example, the maximum angle of internal friction of most soil classes occurs at a moisture content intermediate between maximum and minimum moisture contents.

LITERATURE CITED

1. U. S. Department of Defense, "Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations," MIL-STD-619A, 20 Mar 1962, U. S. Government Printing Office, Washington, D. C.

2. U. S. Department of Agriculture, "Soil Survey Manual," Agricultural Handbook No. 18, Aug 1961, U. S. Government Printing Office, Washington, D. C.

3. U. S. Army Engineer Waterways Experiment Station, CE, "Forecasting Trafficability of Soils," Technical Memorandum No. 3-331, Vicksburg, Miss.

   a. Report 1, "Meteorological and Soil Data, Vicksburg, Mississippi, 1948-1949," Oct 1951.

   b. Report 2, "Meteorological and Soil Data, Vicksburg, Mississippi, 1949-1951," June 1952.

   c. Report 3, "The Development of Methods for Predicting Soil Moisture Content," Oct 1954 (in three volumes and one appendix).

   d. Report 4, "Information for Predicting Moisture in the Surface Foot of Various Soils," Feb 1957.

   e. Report 5, "Development and Testing of Some Average Relations for Predicting Soil Moisture," June 1959.

4. Department of the Army, "Soil Trafficability," Technical Bulletin TB ENG 37, 10 July 1959, U. S. Government Printing Office, Washington, D. C.

5. Cohron, G. T., "Soil Sheargraph," Agricultural Engineering, Vol 44, No. 10, Oct 1963, pp 554-556.

6. U. S. Army Engineer Waterways Experiment Station, CE, "Soil Moisture and Strength," Environmental Data Collection Manual, Vol 2 (unpublished).

7. Rula, A. A., et al, "Environmental Factors Affecting Ground Mobility in Thailand," Technical Report No. 5-625, May 1963 (Appendixes B and C), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

8. Kingdom of Thailand, Ministry of National Development, "Interim Report on the Great Soil Group Survey," Vols I, II, III, and IV, Oct 1964-June 1965.

9. __________, "Interim Reports on Semi-detailed Soil Surveys," Vol I.

10. Pendleton, R. L., Thailand; Aspects of Landscape and Life, Duell, Sloan, and Pearce, New York, 1962.

11. Randolph, D., "An Analytical Model for Predicting Cross-Country Vehicle Performance; Appendix B: Vehicle Performance in Lateral and Longitudinal Obstacles," Technical Report No. 3-783, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss. (in preparation).

12. Department of the Army, "Data Sheets for Ordnance Type Materiel," Technical Manual 9-500, Sept 1962, Washington, D. C.

13. Kennedy, J. G., Collins, J. G., and Smith, M. H., "Moisture-Strength Characteristics of Selected Soils in Thailand," Technical Report No. 3-791, Aug 1967 (in two volumes), U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

14. Meyer, M. P., "Comparison of Engineering Properties of Selected Temperate and Tropical Surface Soils," Technical Report No. 3-732, June 1966, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

BLANK PAGE

Table 1

Characteristics of Surface Composition Classes

Class	Recognition Characteristics	Soils	Drainage	Land Use
1	Tidal flats and coastal depressions; swampy, marshy, or barren; dark tone on photo	Fine-grained, high plasticity, high organic content; OH, MH, CH	Very poor; soil rarely if every dry because of a shallow water table	*
2	Topographic depressions within class 4 areas	Same as class 4 below	Very poor; shallow water table; soil rarely dries out during dry season	*
3	Topographic depressions within class 5 areas	Same as class 5 below	Very poor; shallow water table; soil rarely dries out during dry season	*
4	Alluvial plains, low relief, paddy; termite mounds and trees common	Fine-grained, low plasticity; CL with some CH, ML	Poor	*
5	Drainageways and lower side slopes of class 11; and adjacent rolling areas of low relief with mottled photo tones; generally in paddy, with numerous trees and termite mounds in rolling areas	Fine-grained, low plasticity, occasional coarse-grained soils with fines; CL, ML, with some SM	Variation from good to poor within short distances	*
6	Topographic depressions within class 8 areas	Same as class 8 below	Very poor; shallow water table; soil rarely dries out during dry season	Tilled
7	Topographic depressions within class 10 areas; usually very small in areal extent	Same as class 8 below	Very poor; shallow water table; soil rarely dries out during dry season	Untilled
8	Extremely flat, treeless, uniform alluvial plains. Predominantly paddy without trees or termite mounds	Fine-grained, high plasticity; CH with some CL, MH	Poor	Tilled
9	Areas of broad, low alluvial plains in which slopes exceed 2 percent. Primarily paddy; orchards common in coastal areas. Generally adjacent to more gently sloping areas of class 4	Fine-grained, high and low plasticities; MH, ML, CL, and some SM	Imperfect	*
10	Untilled areas of moderate areal extent associated with and otherwise similar to class 8	Same as class 8	Same as class 8	Untilled
11	Broad, rolling upland areas (high terraces), generally wooded. Separated from surface water bodies by at least 2 percent slope over distance of at least 100 m	SM, with occasional fine-grained soils	Good	*
12	Strong relief features: hills, mountains, and rock terraces. Predominantly uncultivated	Coarse-grained with fines, low or no plasticity; CL, SM, ML, CH with some SC-SM, MH, shallow bedrock	Good	*
13	Natural levees, village platforms. Distinct, generally linear relief features at least 1 to 2 m above surrounding alluvial plains. Villages, orchards, gardens, woods	Fine-grained, low plasticity; CL with SM or SP, ML, CL-ML	Good	Village use
14	Flat to rolling surfaces with mottled tones indicating shallow limestone or hard laterite. Cultivated and uncultivated plots closely intermingled. Areas predominantly cultivated are mapped as class 14 areas; predominantly uncultivated areas are mapped as class 15 areas	Fine-grained, variable plasticity; CL, CH with some SM, shallow bedrock or hard laterite	Prevailingly good but with numerous, small, poorly drained depressions	Tilled
15	Same as class 14	Same as class 14	Same as class 14	Untilled

* No significant effect upon soil strength.

Table 2

Legend for Surface Composition Factor-Family Mapping Units

Map Unit	Soil Mass Strength: Maximum Moisture RCI	Soil Mass Strength: Minimum Moisture RCI	Soil Surface Strength: Maximum Moisture a_{ur}	Maximum Moisture α_{ur}	Minimum Moisture a_{ur}	Minimum Moisture α_{ur}	Conditions Where Maximum a_{ur} Occurs*: a_{ur}	Conditions Where Maximum a_{ur} Occurs*: α_{ur}
1	10-25	>25-60	0-1	0-10	1-2	10-20	Minimum moisture conditions	
2	>25-60	>60-100	0-1	0-10	2-4	20-40	Minimum moisture conditions	
3	>25-60**	>60-100	0-1	10-20	2-4	20-40	Minimum moisture conditions	
4	>25-60	>100	0-1	0-10	0-1	20-40	2-4	20-40
5	>25-60**	>100	0-1	10-20	0-1	20-40	2-4	20-40
6	>60-100	>60-100	0-1	0-10	2-4	20-40	Minimum moisture conditions	
7	>60-100	>60-100	0-1	10-20	0-1	20-40	Minimum moisture conditions	
8	>60-100	>100	0-1	0-10	0-1	20-40	2-4	10-20
9	>60-100	>100	0-1	0-10	0-1	20-40	2-4	20-40
10	>60-100	>100	0-1	10-20	0-1	20-40	Minimum moisture conditions	
11	>60-100**	>100	0-1	10-20	0-1	20-40	1-2	10-20
12	>100	>100	0-1	0-10	0-1	20-40	1-2	10-20
13	>100	>100	0-1	10-20	0-1	20-40	1-2	20-40
14	Complex of >60-100 and >100	>100	0-1	0-10	0-1	20-40	2-4	10-20
15	Complex of >60-100 and >100	>100	0-1	10-20	0-1	20-40	Minimum moisture conditions	

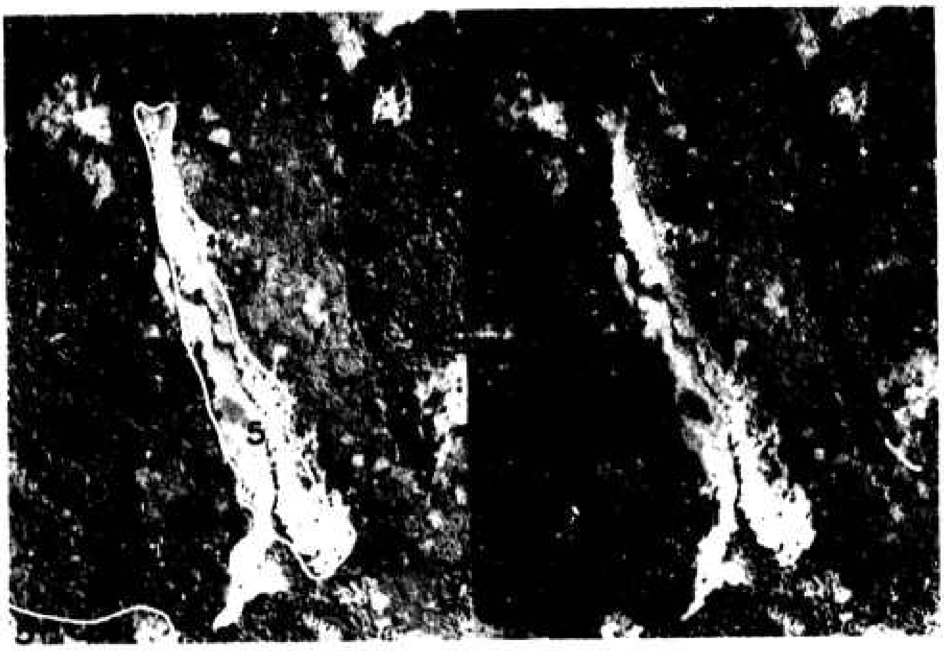
Note: a_{ur}, shear strength at zero normal load, psi. α_{ur}, ultimate angle of internal friction, degrees.

* Maximum surface strength occurs under minimum moisture conditions except where otherwise indicated; e.g. maximum surface strength for map unit 4 occurs with a_{ur} between 2 and 4 and α_{ur} between 20 and 40.

** Maximum moisture has less than 30 percent probability of occurrence during the wet season. Lowest strengths commonly observed are >60-100 for map unit 3 and 5, more than 100 for map unit 11.

Photograph 1. Stereopair of vertical aerial photographs of a part of the Lop Buri study area with surface composition classes 4, 8, and 13 identified

Photograph 2. Stereopair of vertical aerial photographs of a part of the Lop Buri study area with surface composition classes 8 and 15 identified



Photograph 3. Stereopair of vertical aerial photographs in the Khon Kaen study area with surface composition classes 5 and 11 identified

Photograph 4. Stereopair of vertical aerial photographs within the Chanthaburi study area showing surface composition classes 1, 6, 8, and 12

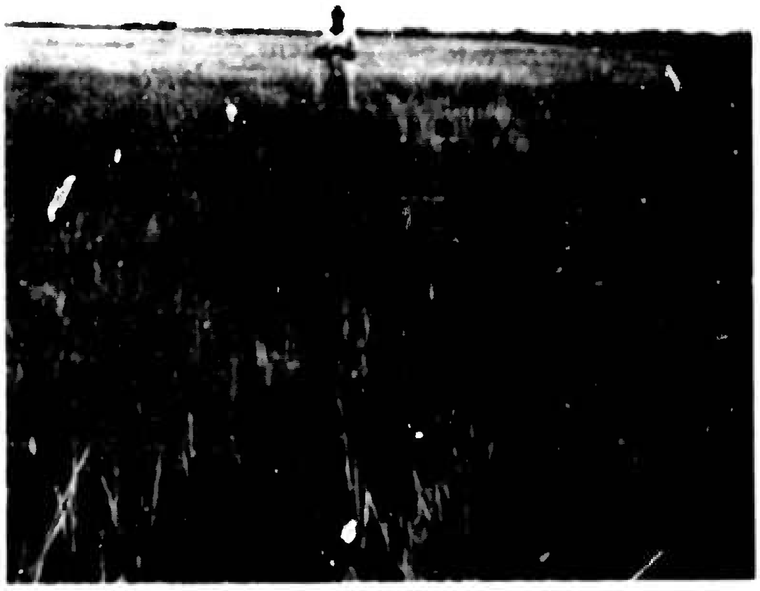
Photograph 5. Site TC-4C in the Nakhon Sawan study area. This site was located on a natural levee and mapped as class 13

Photograph 6. View of Nakhon Sawan site TC-8C, which was classified as surface composition class 12

Photograph 7. Surface composition class 10 that occurs within the Nakhon Sawan study area at site TC-6C

Photograph 8. A rice paddy in the Nakhon Sawan study area where site TC-8E was located. Surface composition at this site was mapped as class 8

Photograph 9. View of site TC-13C in the Lop Buri study area. Surface composition at this site was mapped as class 14



Photograph 10. Lop Buri site TC-10A. This site was located in a rice paddy and was mapped as class 8

Photograph 11. Surface composition site TC-21E in the Chiang Mai study area; mapped as class 4

Photograph 12. View of the Chiang Mai site TC-19A, which was classified as class 12

Photograph 13. Lehn clay at site TC-44C in the Pran Buri study area, which was mapped as class 5

Photograph 14. Pran Buri site TC-39B, which was mapped as surface composition class 5

NAKHON SAWAN STUDY AREA

Table A1

Summary of Surface Composition Field Data

Nakhon Sawan

Map Class*	Site No.	Date Sampled	Location: ARU Map Sheet**	Location: Grid Coords	Figure No.	Topographic Position†	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: a_{ur} †† psi	Sheargraph: α_{ur} ‡ deg	Moisture Content %
12	1-T-1	20/7/64	5057IV	313312	A5	BF	--	64	37	18	19	CL	258	--	--	0.0	29	--
8	1-T-2	21/7/64	5058III	115380	A2	BF	--	34	14	14	0	SM	300	--	--	1.5	21	--
nm	1-T-3	21/7/64	4958I	935603	--	BF	--	65	30	17	13	CL	165	--	--	2.0	29	--
nm	1-T-4	21/7/64	4958I	830660	--	BF	--	45	18	10	8	SC	323	--	--	0.6	25	--
10	1-T-5	22/7/64	5058III	190350	A2	BD	--	99	63	30	33	CH	137	--	--	0.9	15	--
8	1-T-6	22/7/64	5058III	140345	A2	BF	--	81	38	24	14	CL	125	--	--	0.0	31	--
12	1-T-7	22/7/64	5058III	155355	A2	BF	--	38	21	14	7	SM-SC	600	--	--	0.7	27	--
13	1-T-8	22/7/64	5058III	160345	A2	BF	--	66	29	20	9	CL	121	--	--	0.5	23	--
nm	1-T-9	1/8/64	4958I	908652	--	BD	--	84	50	21	29	CH	173	--	--	0.3	37	--
nm	1-T-10	1/8/64	4958I	843675	--	BF	--	81	25	17	8	CL	91	--	--	1.3	24	--
12	1-T-11	4/8/64	5057IV	210320	A5	BF	--	52	25	15	10	CL	183	--	--	0.5	27	--
12	1-T-12	4/8/64	5057IV	210260	A5	BF	--	82	70	23	47	CH	132	--	--	1.6	23	--
nm	1-T-13	4/8/64	5057IV	230140	--	BF	--	80	--	--	--	--	186	--	--	0.8	20	--
nm	1-T-14	4/8/64	5057IV	223147	--	TB	--	--	--	--	--	--	--	--	--	tf‡‡	tf	--
nm	1-T-15	4/8/64	5057IV	200140	--	NL	--	76	36	26	10	ML	429	--	--	0.2	31	--
nm	1-T-16	4/8/64	5057IV	200163	--	BD	--	49	42	18	24	SC	262	--	--	1.8	12	--
nm	1-T-17	4/8/64	5057IV	210190	--	BF	--	70	29	16	13	CL	519	--	--	0.8	30	--
5	1-T-18	5/8/64	4958II	835425	A1	BF	--	51	17	13	4	CL-ML	183	--	--	1.0	18	--
5	1-T-19	5/8/64	4958II	863437	A1	BF	--	65	26	19	7	CL	170	--	--	1.0	24	--
5	1-T-20	5/8/64	4958II	880415	A1	BF	--	--	--	--	--	--	182	--	--	--	--	--
nm	1-T-21	15/8/64	5057IV	261201	--	BF	--	46	21	12	9	SC	101	--	--	1.4	15	--
nm	1-T-22	15/8/64	5057IV	294178	--	BF	--	44	20	15	5	SM-SC	300+	--	--	1.9	22	--
nm	1-T-23	20/8/64	5057I	576207	A4	BF	--	45	23	12	11	SC	97	--	--	1.7	26	--
nm	1-T-24	20/8/64	5057I	570220	A4	BF	--	22	11	NP	--	SM	209	--	--	0.8	28	--
8	1-T-25	20/8/64	5057I	528246	A4	BF	--	54	25	14	11	CL	136	--	--	0.2	33	--
8	1-T-26	20/8/64	5057I	510250	A4	BF	--	46	37	14	23	SC	111	-	--	2.0	8	--
4	1-T-27	20/8/64	5057I	450235	A4	BF	--	88	82	25	57	CH	210	--	--	0.3	27	--
8	1-T-28	20/8/64	5057I	350290	A4	BF	--	51	34	16	18	CL	178	--	--	1.6	28	--
nm	1-TC-1A	18/8/64	5958I	955583	--	BF	0	52	27	13	14	CL	83	0.40	33	1.4	35	18.9
nm	1-TC-1B	18/8/64	5958I	957584	--	T	0	61	33	14	19	CL	132	1.00	132	0.8	32	20.6
nm	1-TC-1C	18/8/64	5958I	950589	--	UD	0	58	24	12	12	CL	58	0.67	34	2.1	27	24.0
nm	1-TC-1D	18/8/64	5958I	950589	--	UF	0	83	33	16	17	CL	133	0.63	84	0.8	31	26.3
nm	1-TC-2A	19/8/64	5958I	975562	--	BF	0	53	36	17	18	CL	305	0.67	204	0.2	25	25.2
nm	1-TC-2B	19/8/64	5958I	978563	--	BF	0	63	21	12	9	CL	140	0.58	81	1.9	28	18.7
nm	1-TC-2C	19/8/64	5958I	982568	--	TS	0.5	67	25	15	10	CL	253	0.70	177	0.0	29	15.7
nm	1-TC-2D	19/8/64	5958I	984570	--	T	0	90	29	17	12	CL	172	0.46	79	1.0	30	25.2
nm	1-TC-2E	19/8/64	5958I	994588	--	T	0	27		--	NP	SM	57	0.56	32	0.2	22	12.1
5	1-TC-3A	19/8/64	4958II	987476	A1	T	0	49	19	14	5	SM-SC	382	0.32	122	0.0	31	10.1
5	1-TC-3B	19/8/64	4958II	993480	A1	BF	0	68	24	14	10	CL	107	0.54	58	0.7	45	21.8
13	1-TC-4A	20/8/64	5058III	115373	A2	NL	0	70	34	20	14	CL	238	0.58	138	0.2	30	20.8
4	1-TC-4B	20/8/64	5058III	115373	A2	SB	0	88	34	20	14	CL	135	0.41	55	1.6	12	22.5
13	1-TC-4C	20/8/64	5058III	115374	A2	NL	11	65	21	16	5	CL-ML	607+	1.86	1129+	0.6	13	14.2
5	1-TC-4D	20/8/64	5058III	101395	A2	BF	0	42	12	10	2	SM	87	0.22	19	0.0	20	13.3
13	1-TC-4E	20/8/64	5058III	110392	A2	T	0	41	15	14	1	SM	151	2.05	310	0.2	22	12.0
nm	1-TC-5A	21/8/64	5057IV	213215	--	LS	0.5	75	42	24	18	CL	255	--	tf	0.0	27	23.7
nm	1-TC-5B	21/8/64	5057IV	215214	--	LB	0.5	69	31	17	14	CL	211	1.23	260	0.2	30	20.1
nm	1-TC-5C	21/8/64	5057IV	224212	--	US	13	60	27	25	2	ML	750+	--	tf	--	--	15.8
nm	1-TC-5D	21/8/64	5057IV	227211	--	UF	0	82	43	24	19	CL	750+	--	tf	0.0	28	14.1
nm	1-TC-5E	21/8/64	5057IV	233209	--	UD	0	68	41	16	25	CL	129	0.70	90	0.7	13	26.4
13	1-TC-6A	22/8/64	5058[illegible]	207343	A2	NL	0	85	30	20	10	CL	277	0.62	172	0.0	31	28.4
12	1-TC-6B	22/8/64	5058III	207342	A2	BF	0	52	36	17	19	CL	693+	--	tf	0.2	27	23.5
10	1-TC-6C	22/8/64	5058III	207341	A2	BF	0	80	55	21	34	CH	80	0.81	55	0.4	15	30.4
10	1-TC-6D	22/8/64	5058III	207341	A2	T	0	81	56	20	36	CH	93	0.81	75	0.0	26	32.6
12	1-TC-6E	22/8/64	5058III	207341	A2	LS	1	86	70	27	43	CH	139	0.94	131	0.0	19	35.1
6	1-TC-7A	23/8/64	5057IV	226322	A5	BF	0	90	49	21	28	CL	96	0.72	69	0.1	7	36.5
12	1-TC-7B	23/8/64	5057IV	227322	A5	TB	4	51	35	18	17	CL	543+	--	tf	0.2	15	22.8
12	1-TC-7C	23/8/[illegible]	[illegible]71V	227322	A5	T	0	73	60	28	32	CH	321	--	tf	0.7	19	26.6
12	1-TC-7D	23/[illegible]	[illegible]7IV	244318	A5	T	0	52	39	23	16	CL	713+	--	tf	1.4	11	10.5
4	1-TC-7E	23/[illegible]	[illegible]571V	244318	A5	BF	0	58	28	12	16	CL	79	0.48	38	0.3	5	16.5
4	1-TC-7F	23/8/[illegible]	5057IV	243318	A5	BD	0	66	28	12	16	CL	271	0.48	130	1.0	[illegible]	17.9
12	1-TC-8A	24/8/64	5057IV	206259	A5	BF	0	66	30	16	14	CL	142	1.00	142	0.0	14	17.9
12	1-TC-8B	24/8/64	5057IV	206259	A5	TS	0.5	82	63	23	40	CH	382	--	tf	1.0	9	22.3
12	1-TC-8C	24/8/64	5057IV	233266	A5	US	5	48	25	18	7	SM-SC	750+	--	tf	1.0	12	8.7
12	1-TC-8D	24/8/64	5057IV	217268	A5	SB	0	95	35	28	7	ML	741+	--	tf	0.7	15	8.4
8	1-TC-8E	24/8/64	5057IV	207264	A5	BF	0	57	31	17	14	CL	127	0.74	94	3.4	7	32.6
12	1-TC-9A	25/8/64	5057IV	209322	A5	BF	0	59	43	19	24	CL	168	0.66	111	0.0	5	34.5
nm	1-TC-9B	25/8/64	5057IV	214187	A5	BD	0	23	26	13	13	GC	430+	--	tf	0.0	11	12.6
nm	1-TC-9C	25/8/64	5057IV	214187	A5	BF	0	41	18	12	6	SM-SC	750+	--	tf	0.0	14	6.8
nm	1-SGT-20	18/8/64	4958I	989526	--	BF	--	78	39	18	21	CL	281	--	--	0.2	35	--
5	1-SGT-23	18/8/64	4958II	900426	A1	BF	--		22	15	7	CL-ML	178	--	--	0.2	27	--
5	1-SGT-27	18/8/64	4958II	997446	A1	BF	--	52	28	13	15	CL	277	--	--	0.2	47	--
nm	1-SOT-30	19/8/64	5057IV	233146	A5	BF	--	67	16	12	4	CL-ML	530	--	--	1.0	24	--

Note: All soil strength measurementa except sheargraph measurementa were made at a 15- to 30.5-cm depth. Sheargraph measurements were made at the surface.

* nm, not mapped.

** Series L708, scale 1:50,000.

† BF, bottomland flat; BD, bottomland depression; LS, lower slope; MS, middla alope; NL, natural levee; T, terrace; TS, terrace slope; SB, stream bottom; UD, upland depression; UF, upland flat; US, upper slope.

†† a_{ur} , shear atrength at zero normal load.

‡ α_{ur} , ultimate angle of internal friction.

‡‡ tf, too firm

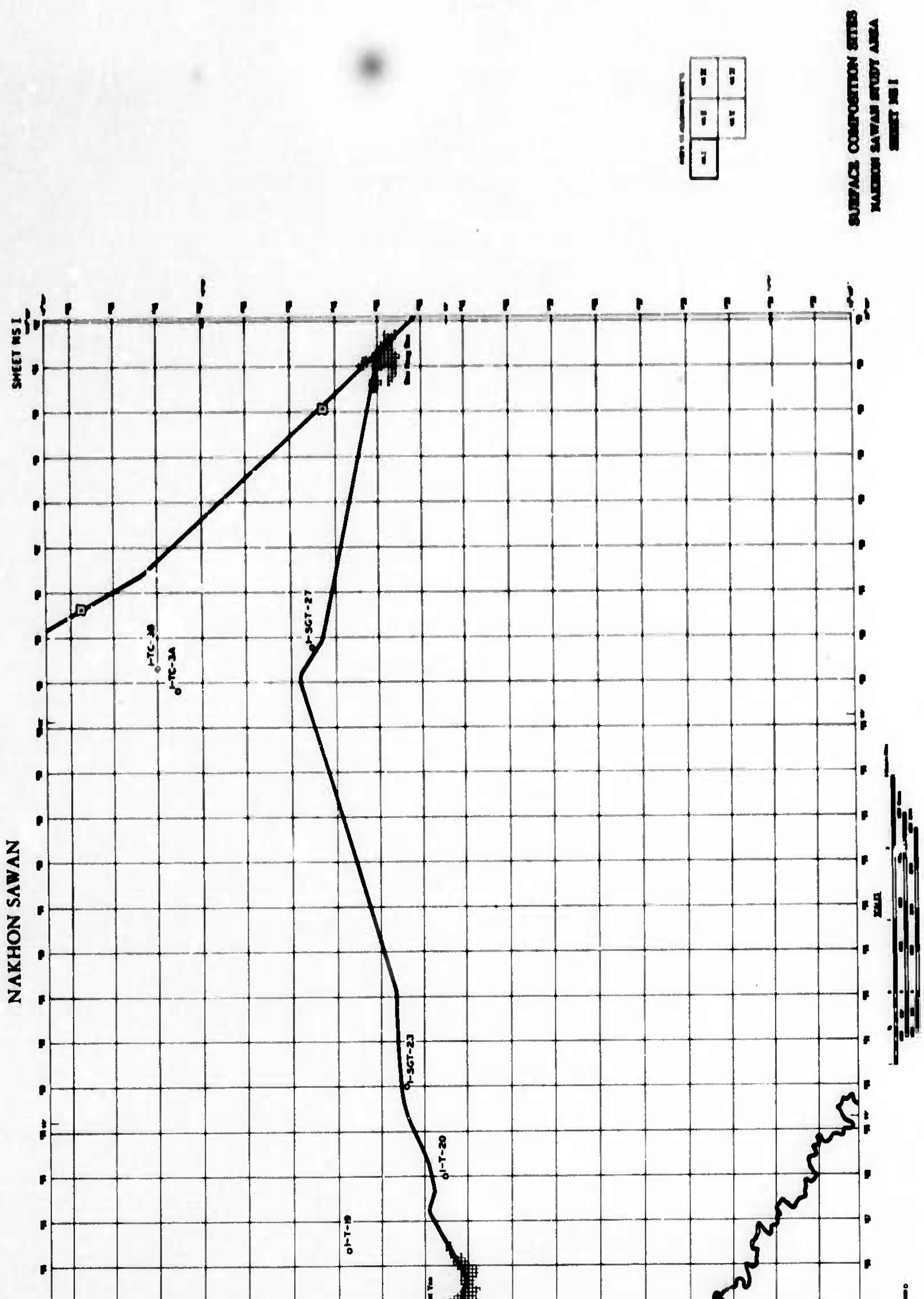

NAKHON SAWAN
SHEET NS 1
SURFACE COMPOSITION SITES
NAKHON SAWAN STUDY AREA
SHEET NS 1
1-TC-3B
1-TC-3A
1-SGT-27
1-SGT-23
1-T-20
1-T-19
1-T-18

FIG. A1

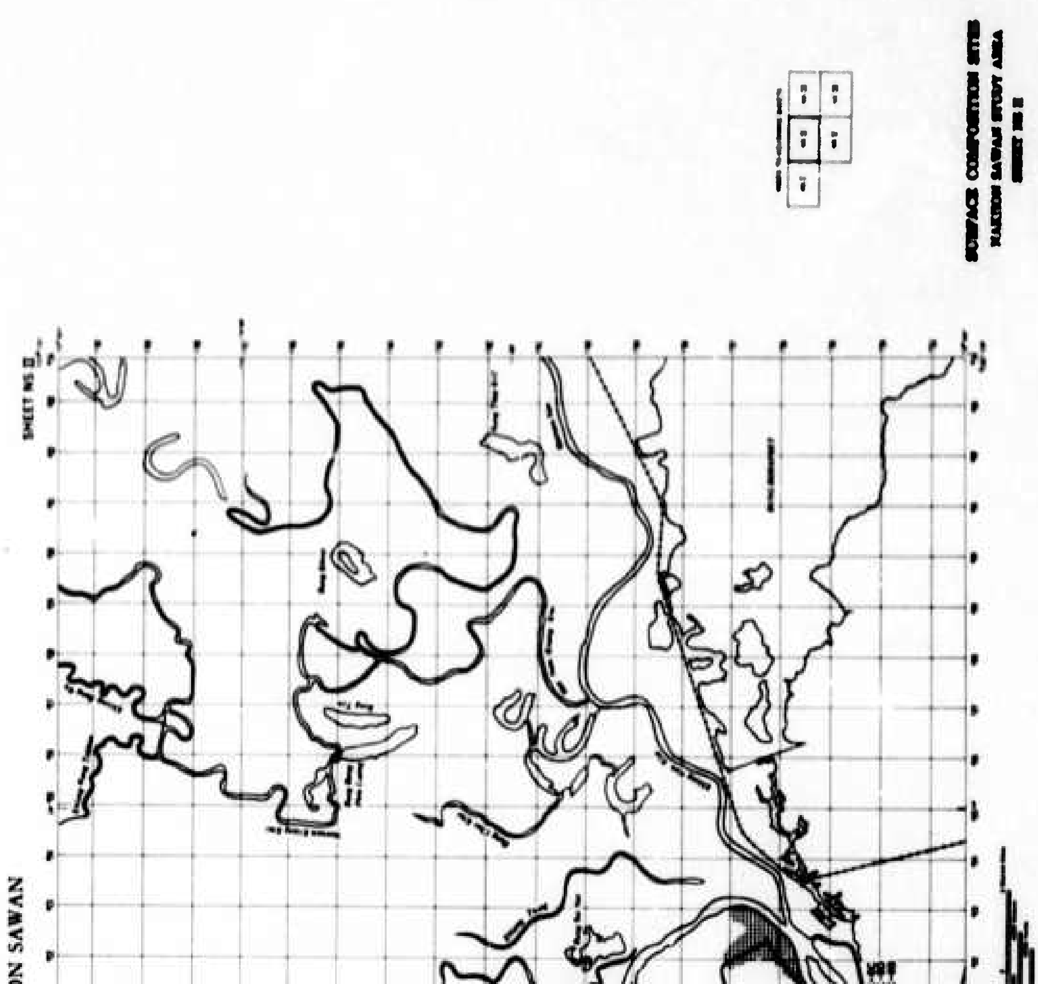


FIG. A2

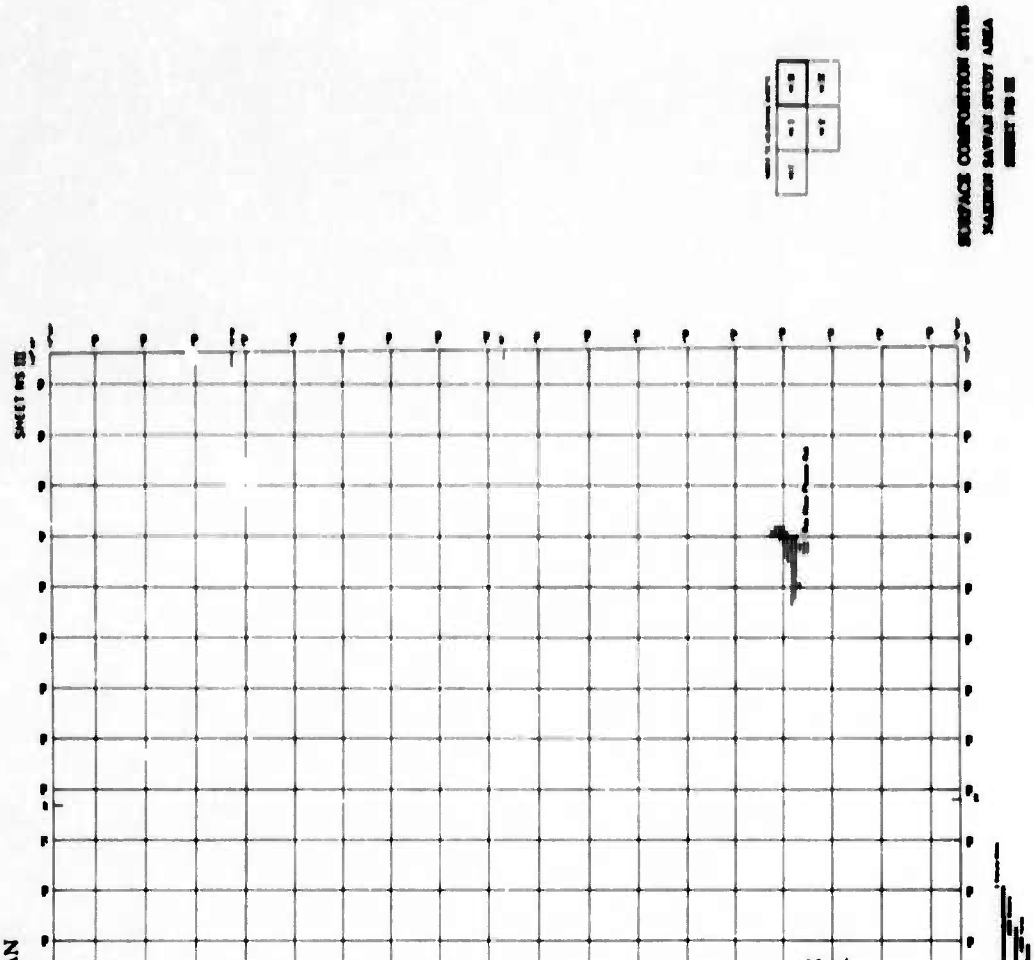


FIG. A3

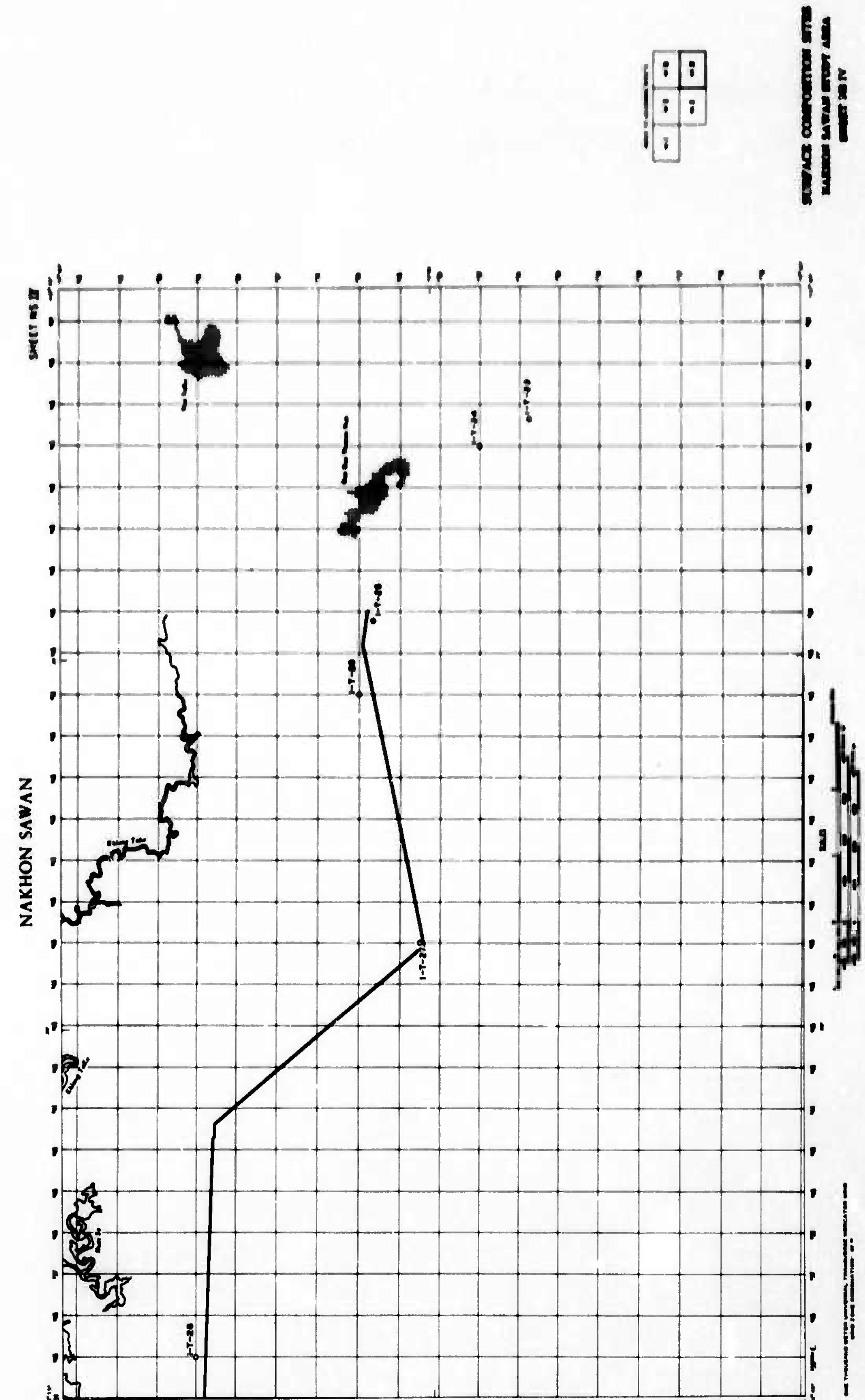


FIG. A4

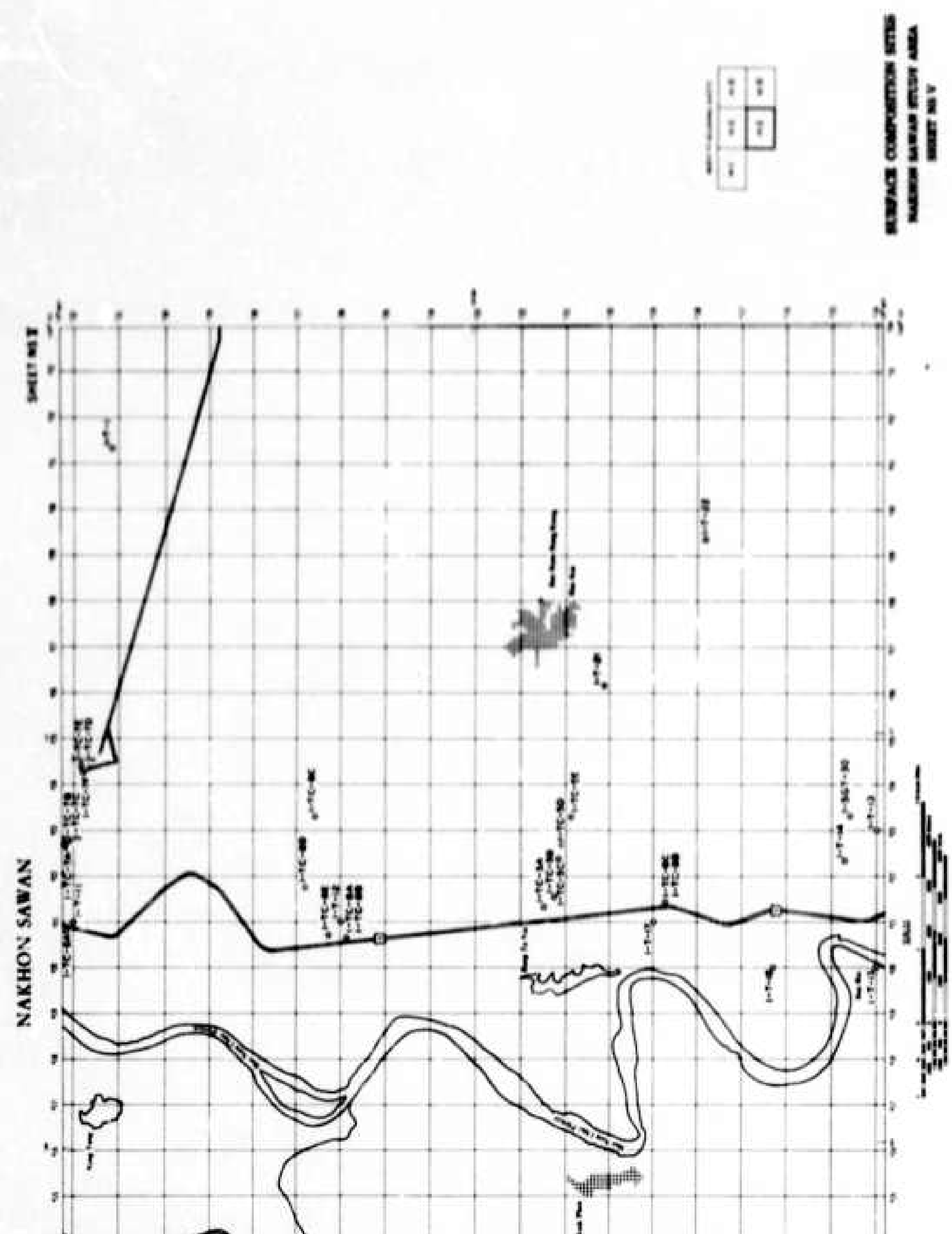


FIG. A5

LOP BURI STUDY AREA

BLANK PAGE

Table A2 (Concluded)

Map Class	Site No.	Date Sampled	Location: AMS Map Sheet	Location: Grid Coords	Location: Figure No.	Topographic Position	Slope %	Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Cone Index	Remolding Index	Rating Cone Index	Sheargraph: c_{ur} psi	Sheargraph: ϕ_{ur} deg	Moisture Content %
8	2-TC-16B	4/9/64	5154I	123125	A9	T	0	60	27	23	4	ML	356	1.07	381	0.0	17	15.9
4	2-TC-16C	4/9/64	5154I	102074	A9	NL	0	89	37	22	15	CL	70	0.61	43	0.0	20	27.0
4	2-TC-16D	4/9/64	5154I	103076	A9	BD	0	98	62	22	40	CH	95	0.48	46	0.0	12	31.5
12	2-TC-16E	4/9/64	5154I	104077	A9	LS	3	86	38	21	17	CL	201	0.68	137	0.0	12	25.8
4	2-TC-17A	5/9/64	5154II	038929	A10	BF	0	77	31	19	12	CL	116	0.56	65	0.0	6	25.5
4	2-TC-17B	5/9/64	5154II	037931	A10	T	0	69	67	23	44	CH	198	0.65	129	2.4	5	28.0
4	2-TC-17C	5/9/64	5154II	037932	A10	LS	1	92	59	21	38	CH	106	0.39	41	1.1	10	28.5
4	2-TC-17D	5/9/64	5154II	059995	A9	BF	0	81	26	18	8	CL	165	0.24	40	0.0	16	16.9
12	2-TC-17E	5/9/64	5154II	060999	A9	TS	1	92	--	NP	NP	ML	750+	--	tf††	0.0	16	13.3
12	2-TC-17F	5/9/64	5154II	060999	A9	TS	0.5	90	NP	NP	NP	ML	750+	--	tf	1.8	18	21.0
5	2-TC-18A	6/9/64	5154II	102988	A9	BD	0	63	17	16	1	ML	205	0.15	31	0.0	14	25.5
13	2-TC-18B	6/9/64	5154II	101989	A9	TS	1	72	17	16	1	ML	379	0.48	182	0.0	18	16.3
13	2-TC-18C	6/9/64	5154II	101991	A9	T	0	54	--	--	NP	ML	433	1.66	719	0.8	14	15.9
4	2-TC-18D	6/9/64	5154II	081012	A9	T	0	57	--	--	NP	ML	687+	0.46	316+	0.0	11	18.9
8	2-HR-9	7/6/62	5153I	105824	A10	BF	0	94	77	39	38	MH	193	1.00	193+	--	--	34.9
12	2-HR-170	8/9/62	5154II	142990	A9	LS	15	28	25	17	8	SC	67	--	--	--	--	18.4
5	2-HR-171	8/9/62	5154II	140984	A9	LS	52	52	17	16	1	ML	118	0.33	39	--	--	19.8
5	2-HR-172	8/9/62	5154II	121997	A9	BD	0	43	26	21	5	SM-SC	68	0.12	8	--	--	23.8
4	2-HR-173	8/9/62	5154II	115004	A9	BF	0	47	16	14	2	SM	51	0.27	14	--	--	22.9
5	2-HR-174	8/9/62	5154II	095994	A9	US	2	52	17	17	0	ML	60	0.17	10	--	--	22.8
4	2-HR-175	8/9/62	5154II	078013	A9	BF	0	63	18	14	4	CL-ML	106	0.22	23	--	--	20.4
4	2-HR-176	8/9/62	5154II	071019	A9	T	0	77	18	16	2	ML	300+	--	--	--	--	20.8
8	2-HR-186	8/9/62	5155III	656379	A7	BF	0	93	46	22	24	CL	430	1.00	430+	--	--	--
8	2-HR-187	8/9/62	5155III	661379	A7	BD	0	97	59	27	32	CH	117	1.00	117	--	--	--
8	2-HR-188	8/9/62	5155III	663374	A7	BF	0	--	--	--	--	CH	750	1.00	750+	--	--	--
10	2-HR-189	8/9/62	5155III	803349	A7	BF	0	76	48	25	23	CL	155	1.00	155+	--	--	--
10	2-HR-190	8/9/62	5155III	800356	A7	BF	0	--	70	30	40	CH	65	1.00	65	--	--	--
12	2-HR-194	8/9/62	5155IV	828440	A6	UF	0	--	--	--	--	CL	107	--	--	--	--	--
8	2-HR-195	9/9/62	5155III	865315	A7	BF	0	93	89	43	46	MH	77	0.84	65	--	--	--
14	2-HR-196	9/9/62	5155II	914228	A8	BF	0	--	116	44	72	CH	67	--	--	--	--	--
14	2-HR-197	9/9/62	5154I	904209	A8	BF	0	--	--	--	--	CH	94	--	--	--	--	--
8	2-HR-199	9/9/62	5154I	043172	A8	BF	0	--	--	--	--	--	238	1.00	238+	--	--	--
8	2-HR-200	9/9/62	5154I	043170	A8	BF	0	--	--	--	--	--	175	1.00	175+	--	--	--
8	2-HR-201	9/9/62	5154I	046193	A8	BF	0	63	34	17	17	CL	101	--	--	--	--	23.4
4	2-HR-202	9/9/62	5155II	004236	A8	BF	0	83	37	18	19	CL	97	0.68	66	--	--	22.6
8	2-HR-203	10/9/62	5155II	916276	A8	BF	0	--	--	--	--	CH	119	--	--	--	--	--
8	2-HR-204	10/9/62	5155II	897262	A8	BF	0	--	--	--	--	CL	89	--	--	--	--	--
8	2-HR-205	10/9/62	5155II	878264	A8	BF	0	--	--	--	--	CL	87	--	--	--	--	--
8	2-HR-206	10/9/62	5154I	136104	A9	BF	--	92	61	22	39	CH	88	0.84	74	--	--	--
4	2-HR-207	10/9/62	5154I	134103	A9	BF	0	--	--	--	--	CH	94	--	--	--	--	--
4	2-CR-1	4/9/64	5154I	946123	A9	--	--	93	57	22	35	CH	112	--	--	--	--	28.4
8	2-CR-2	4/9/64	5153IV	820785	A11	--	--	95	69	25	44	CH	127	--	--	--	--	--
8	2-CR-5	5/9/64	5155II	928265	A8	--	--	87	70	27	43	CH	82	--	--	--	--	--
nm	2-CR-6	5/9/64	5154IV	868128	--	--	--	93	59	28	31	CH	98	--	--	--	--	42.4
nm	2-CR-7	5/9/64	5155II	960348	--	--	--	94	84	30	54	CH	143	--	--	--	--	--
4	2-CR-11	6/9/64	5155III	618397	A7	NL	--	89	46	24	22	CL	221+	--	--	--	--	--
4	2-CR-14	7/9/64	5154I	130879	A10	--	--	98	28	21	7	CL-ML	156+	--	--	--	--	26.5
4	2-CR-17	8/9/64	5154I	023087	A9	--	--	81	47	20	27	CL	66	--	--	--	--	24.6
8	2-CR-19	14/9/64	5154I	045089	A9	--	--	96	54	24	30	CH	102	0.92	94	--	--	24.5
4	2-CR-20	14/9/64	5154I	084093	A9	--	--	94	57	22	35	CH	101	0.43	43	--	--	28.1
8	2-CR-21	14/9/64	5154I	021130	A8	--	--	79	32	22	10	CL	224+	0.19	43+	--	--	29.4
8	2-CR-23	14/9/64	5154I	053164	A8	--	--	88	51	21	30	CH	71	0.72	52	--	--	27.8
nm	2-CR-27	15/9/64	5154II	623946	--	NL	--	92	39	24	15	CL	300+	--	tf	--	--	25.5
nm	2-CR-28	15/9/64	5154IV	657900	--	--	--	92	53	27	26	CH	300+	--	tf	--	--	20.2
nm	2-CR-30	15/9/64	5153I	891751	--	--	--	79	69	35	34	MH	117	0.49	57	--	--	35.5
8	2-CR-31	15/9/64	5153I	948788	A10	--	--	87	62	27	35	CH	91	0.83	76	--	--	34.8
8	2-CR-33	16/9/64	5153I	983793	A10	--	--	83	79	39	40	MH	150	0.99	149	--	--	41.9
9	2-CR-37	16/9/64	5154II	040917	A10	--	--	70	25	15	10	CL	95	1.00	95	--	--	21.2
4	2-CR-39	17/9/64	5154II	071907	A10	--	--	81	19	19	0	ML	750+	--	--	--	--	15.7
4	2-CR-41	17/9/64	5154II	081873	A10	--		78	20	17	3	ML	189	0.63	116	--	--	20.8
4	2-CR-44	17/9/64	5154I	908152	A9	--	--	89	63	40	23	MH	--	--	--	--	--	37.7
9	2-CR-46	18/9/64	5154II	040963	A9	--	--	96	61	35	26	MH	85	1.02	87	--	--	31.9
9	2-CR-47	18/9/64	5154II	053974	A9	--	--	32	--	--	NP	SM	750+	--	tf	--	--	13.8
4	2-CR-48	18/9/64	5154II	[illegible]	A9	--	--	85	17	16	1	ML	750+	--	--	--	--	20.1
8	2-CR-49	18/9/64	5154I	123124	A9	--	--	58	21	--	NP	ML	194+	0.46	89+	--	--	20.6
4	2-CR-50	18/9/64	5154I	116087	A9	--	--	84	54	22	32	CH	59	1.08	64	--	--	25.1
8	2-CR-54	19/9/64	5154I	011092	A9	--	--	96	49	23	26	CL	105	0.99	104	--	--	27.0
8	2-CR-56	19/9/64	5154I	972150	A9	--	--	83	40	18	22	CL	148	1.00	148	--	--	21.9
nm	2-CR-59	19/9/64	5154IV	881164	--	--	--	95	88	30	58	CH	50	1.28	64	--	--	47.2
nm	2-CR-60	19/9/64	5154IV	881164	--	--	--	87	62	26	36	CH	110	1.16	128	--	--	27.5
14	2-CR-62	20/9/64	5154I	993210	A8	--	--	83	66	30	36	CH	131	1.20	157+	--	--	29.3
nm	2-CR-63	20/9/64	5155III	850240	A7	--	--	91	73	42	31	CH	49	1.33	65	--	--	39.7
8	2-CR-64	20/9/64	5155II	895262	A8	--	--	86	58	26	32	CH	107	1.39	149	--	--	30.7
8	2-CR-65	20/9/64	5155III	791363	A7	--	--	87	63	29	34	CH	79	1.06	84	--	--	27.5
8	2-CR-66	21/9/64	5155II	028252	A8	--	--	67	40	21	19	CL	174	1.29	225	--	--	--
10	2-CR-67	21/9/64	5155II	961276	A8	--	--	63	59	25	34	CH	159	1.01	161	--	--	26.9
8	2-CR-69	21/9/64	5155II	945303	A8	--	--	91	52	24	28	CH	137	0.86	118	--	--	24.6
8	2-CR-70	21/9/64	5155III	785348	A7	--	--	92	74	41	33	CH	129	0.98	126	--	--	36.2
14	2-CR-71	21/9/64	5155III	773402	A7	--	--	58	36	20	18	CL	125	0.71	89	--	--	17.3
8	2-CR-72	22/9/64	5155III	837334	A7	--	--	76	57	28	29	CH	109	1.00	109	--	--	29.0
12	2-CR-73	22/9/64	5155III	819380	A7	--	--	75	44	20	24	CL	92	0.80	74	--	--	20.6
4	2-CR-74	22/9/64	5155III	773329	A7	--	--	88	46	16	30	CL	69	0.93	64	--	--	27.3
4	2-CR-75	22/9/64	5155IV	737439	A6	--	--	78	63	23	40	CH	116	1.09	125	--	--	31.1
4	2-CR-77	22/9/64	5155IV	764440	A6	--	--	83	48	17	31	CL	84	1.50	126	--	--	26.7
12	2-CR-79	26/9/64	5155IV	838301	A6	--	--	51	27	10	12	CL	300+	--	--	--	--	12.1
12	2-CR-81	26/9/64	5155IV	788475	A6	--	--	85	51	20	31	CH	--	--	--	--	--	26.3
4	2-CR-83	26/9/64	5155IV	782570	A6	--	--	27	31	22	9	SC	282+	--	--	--	--	22.6
8	2-CR-84	26/9/64	5155IV	773598	A6	--	--	53	33	16	17	CL	199+	0.85	169+	--	--	18.2
8	2-CR-86	27/9/64	5154III	732893	A11	--	--	97	55	25	30	CH	127	1.01	128	--	--	28.6
8	2-CR-87	27/9/64	5154III	717860	A11	--	--	98	54	25	29	CH	110	0.85	94	--	--	26.4
4	2-CR-88	28/9/64	5154I	908135	A8	--	--	87	72	28	44	CH	76	0.93	71	--	--	--

†† tf, too firm.

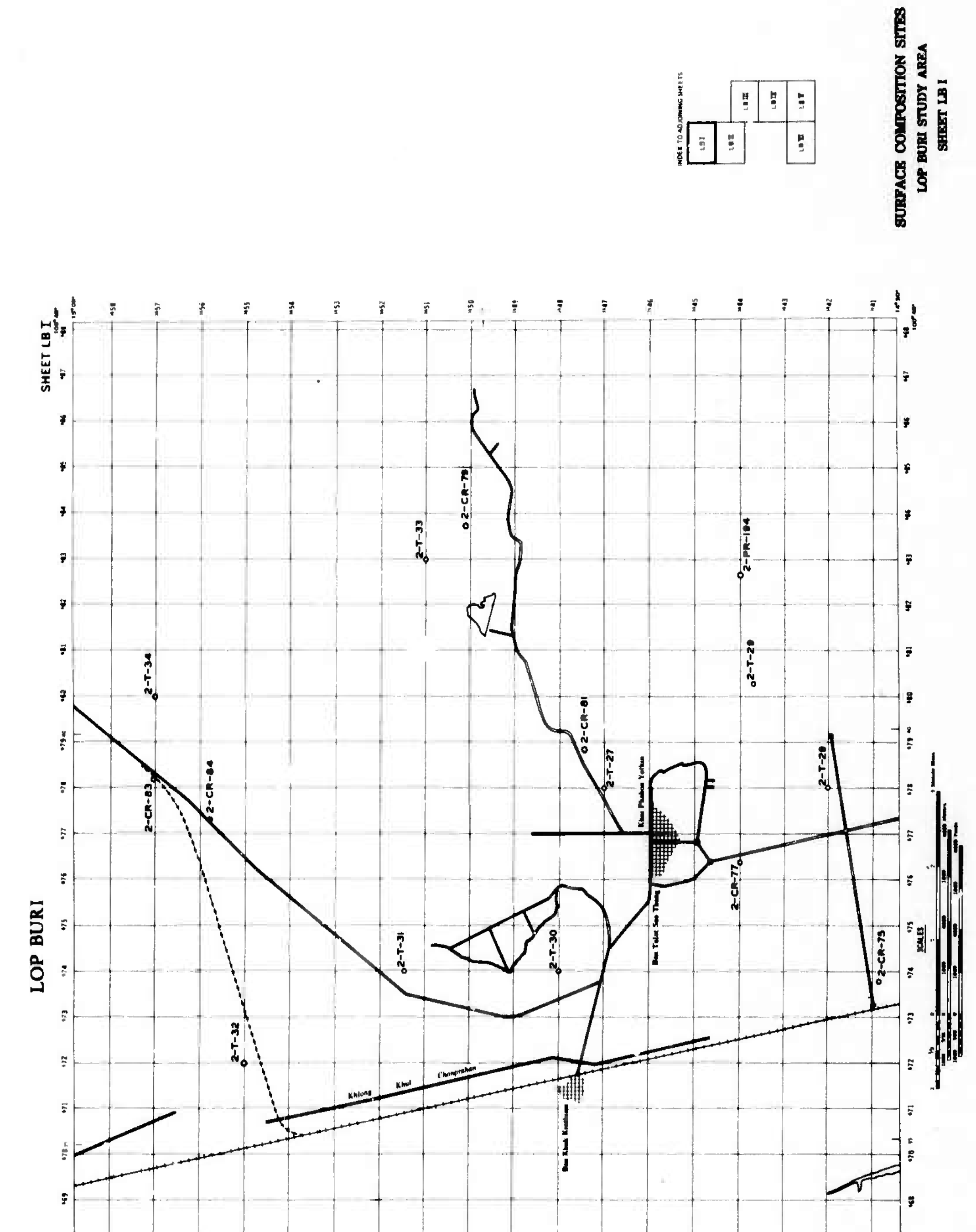

LOP BURI
SHEET LB I
SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB I
2-T-34
2-CR-83
2-CR-84
2-T-32
2-T-31
2-T-30
2-T-33
2-CR-79
2-CR-81
2-T-27
2-PR-104
2-T-29
2-CR-77
2-CR-75
2-T-28

FIG. A6

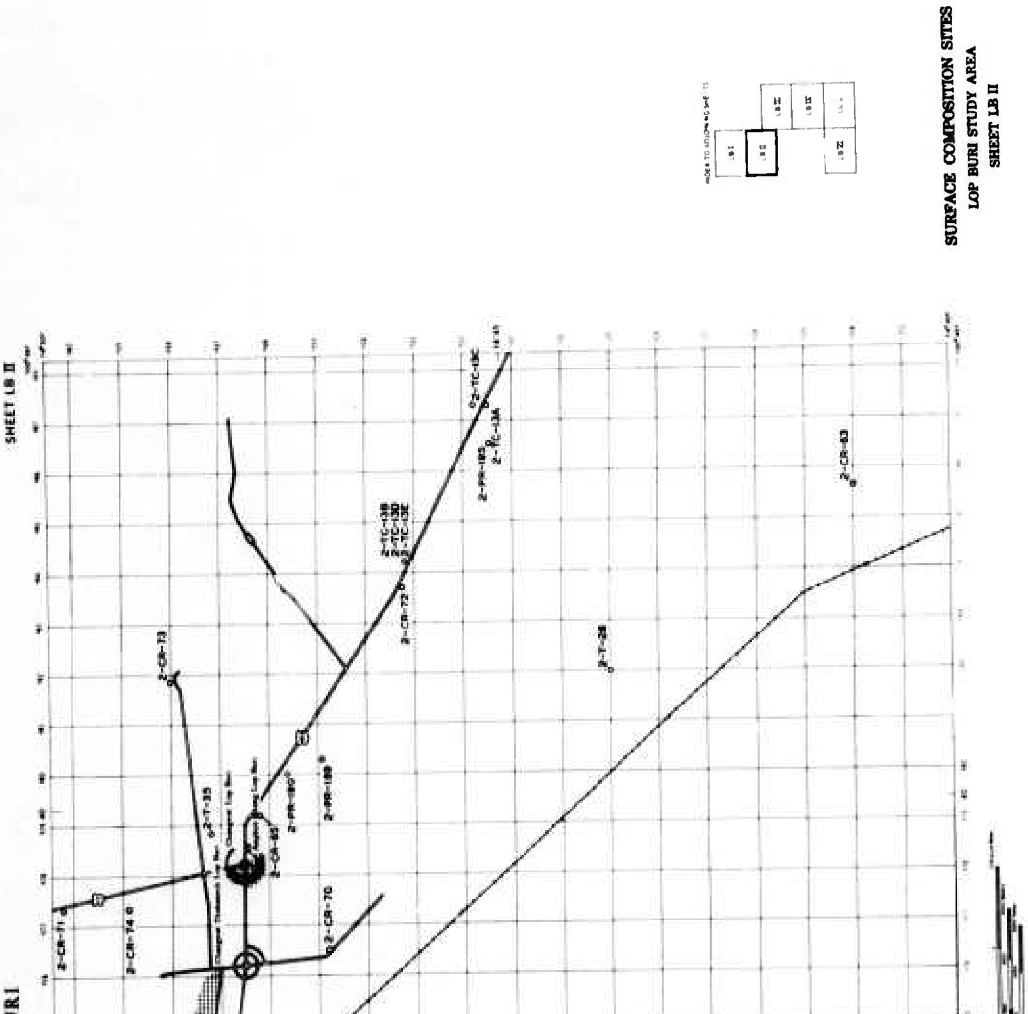
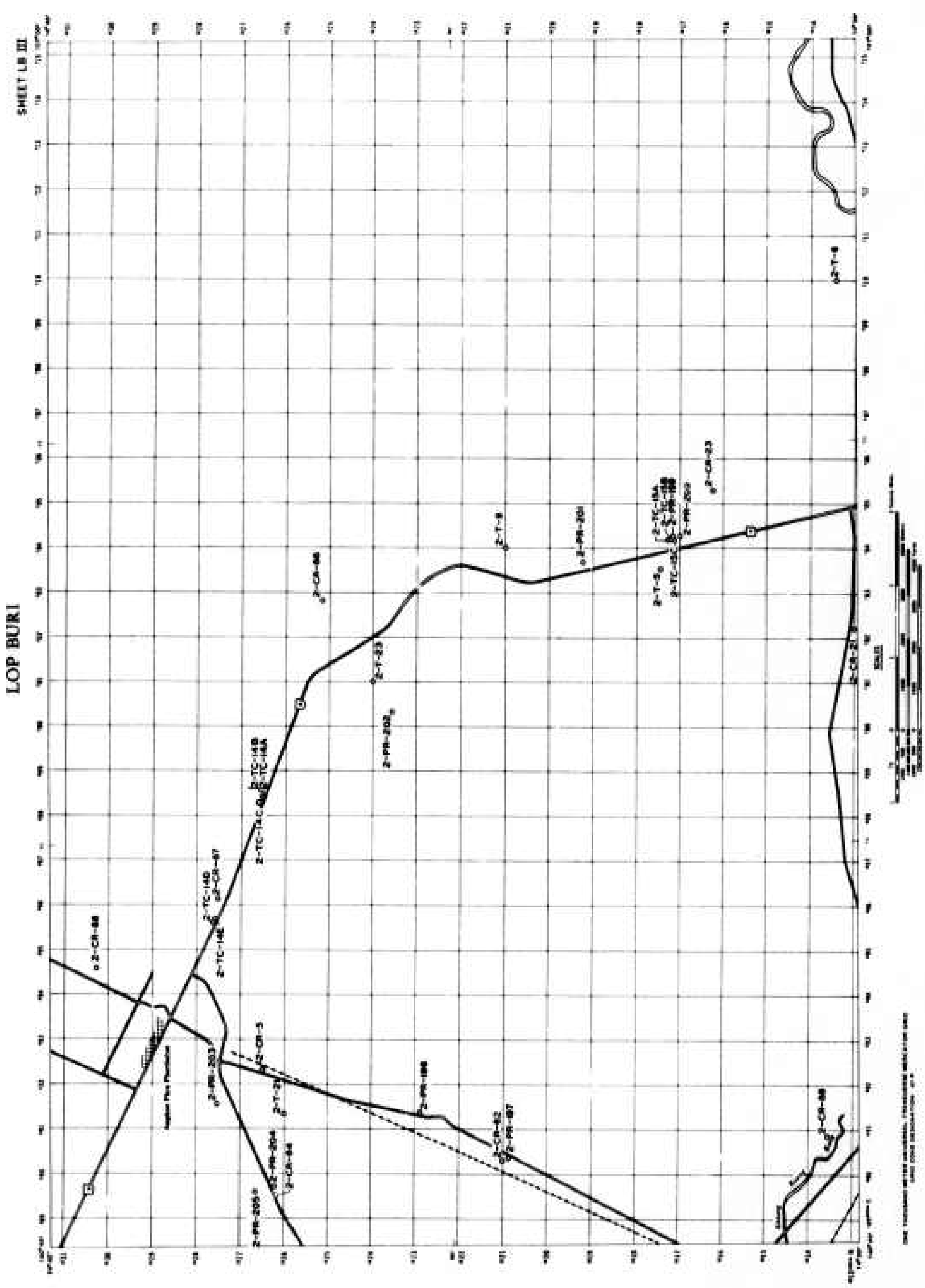
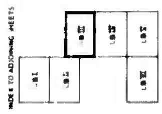

LOP BURI
SHEET LB II
SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB II

FIG. A7





SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB III

FIG. A8

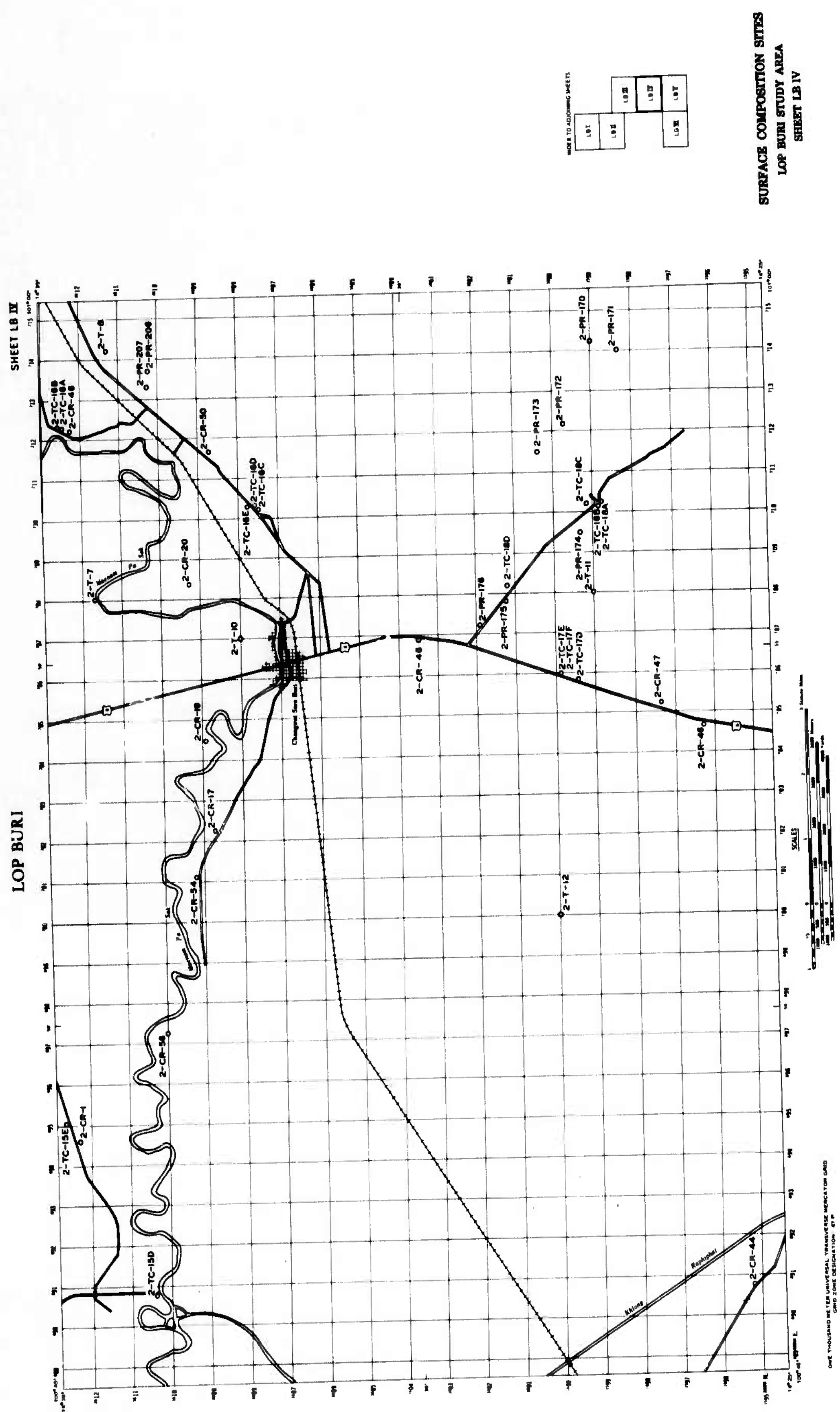
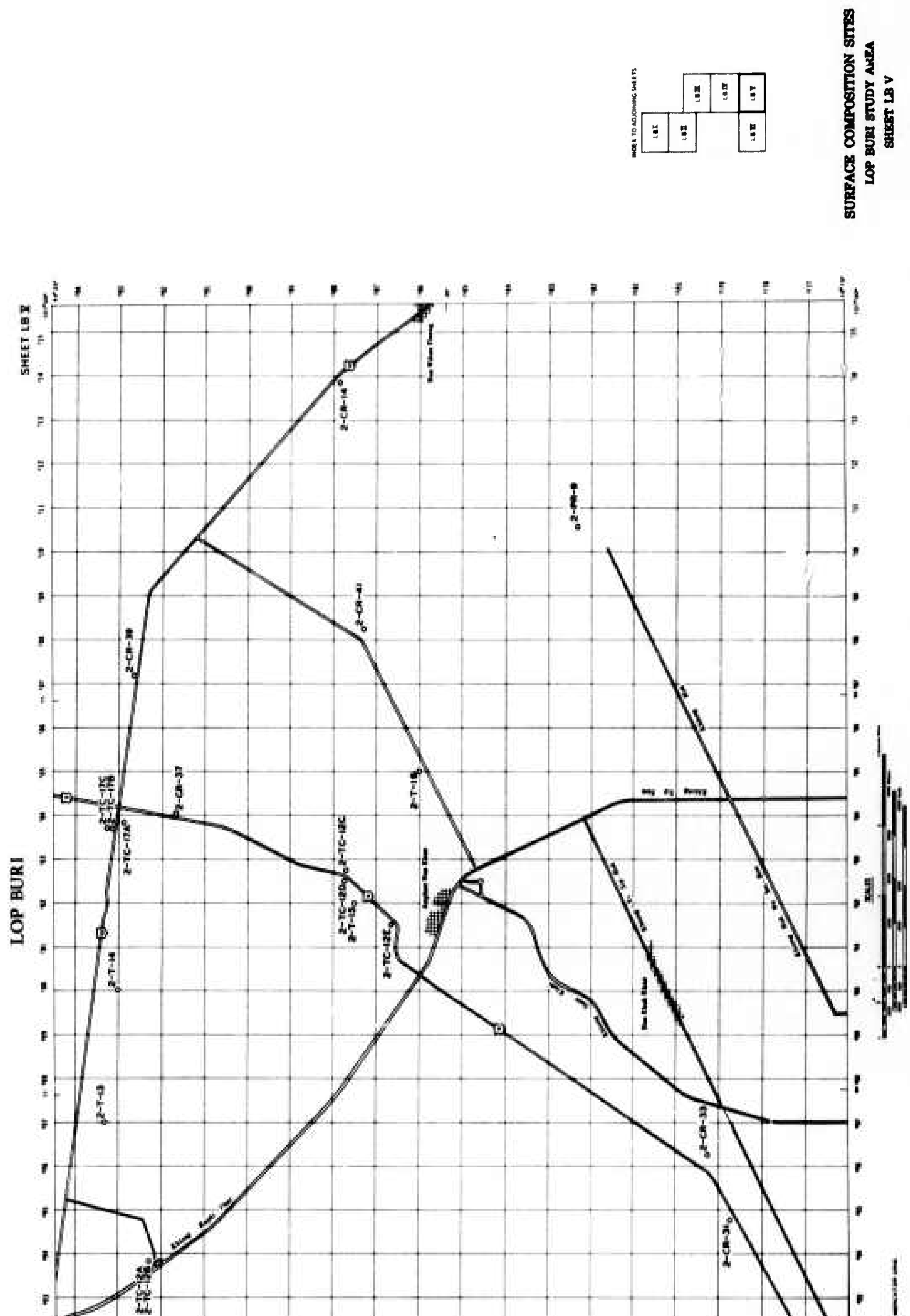

LOP BURI
SHEET LB IX
SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB IV
SCALES

FIG. A9


LOP BURI
SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB V
2-CR-14
2-CR-39
2-CR-42
2-CR-37
2-CR-33
2-CR-31
2-PR-8
2-T-14
2-T-13
2-T-16
2-TC-17A
2-TC-12C
2-TC-12E

A17

FIG. A10

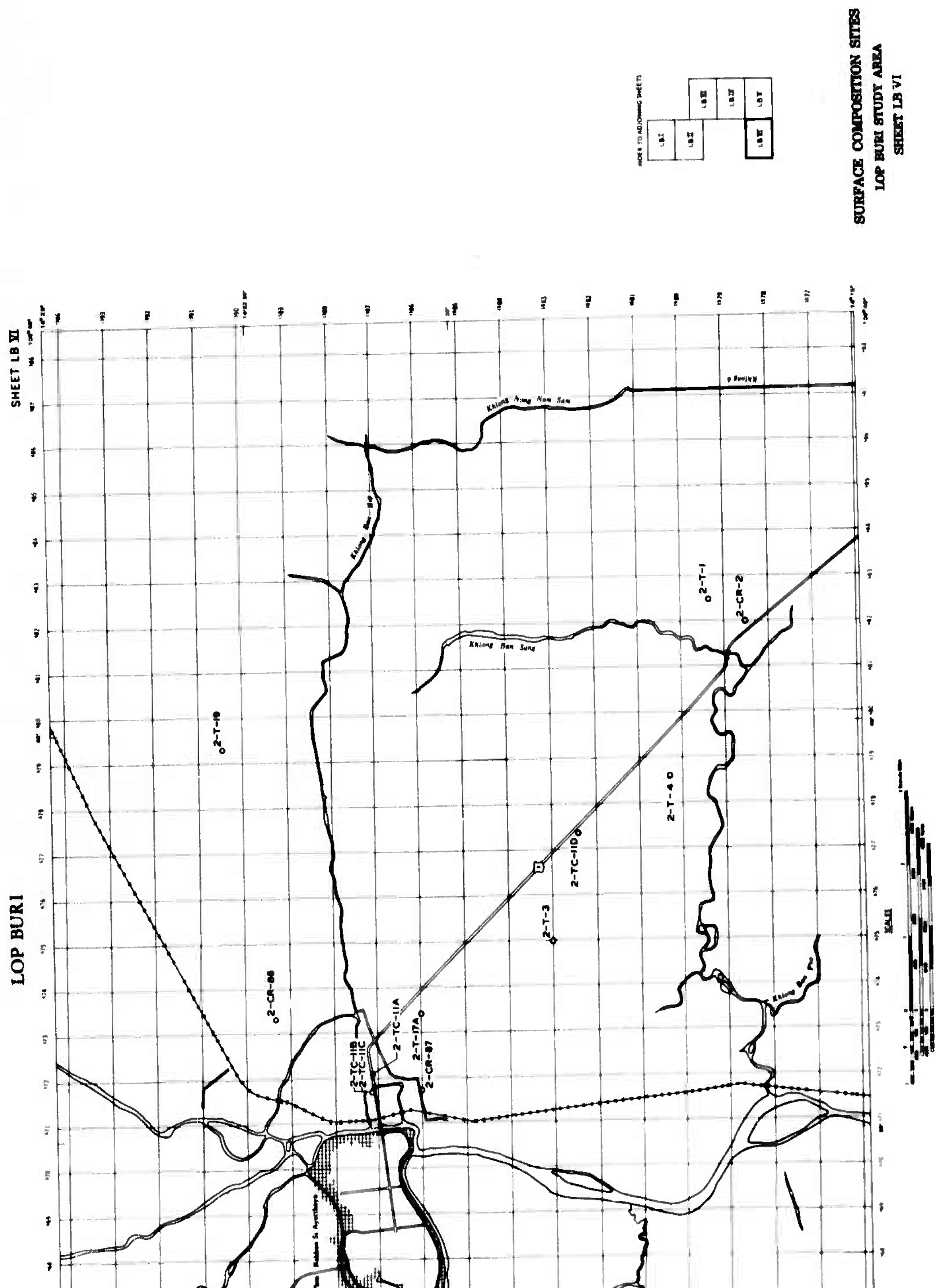

LOP BURI
SHEET LB VI
SURFACE COMPOSITION SITES
LOP BURI STUDY AREA
SHEET LB VI
SCALE
Khlong Nong Nam San
Khlong Ban Sang
Khlong Ban Pu
2-T-19
2-CR-86
2-TC-11B
2-TC-11C
2-TC-11A
2-T-17A
2-CR-87
2-T-3
2-TC-11D
2-T-4
2-T-1
2-CR-2

FIG. A11

CHIANG MAI STUDY AREA

BLANK PAGE

Table A3

Summary of Surface Composition Field Data

Chiang Mai

Map Class*	Site No.	Date Sampled	Location: AMS Map Sheet**	Location: Grid Coords	Location: Figure No.	Topographic Element†	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: a_{ur}†† psi	Sheargraph: α_{ur}‡ deg	Moisture Content %
11	3-T-1	4/10/64	4767I	968842	A12	--	--	--	--	--	--	--	138	0.48	66	1.3	27	--
nm	3-T-2	4/10/64	4767I	950891	A12	--	--	--	--	--	--	--	121	0.66	80	0.7	27	--
nm	3-T-3	5/10/64	4767I	942909	A12	--	--	--	--	--	--	--	74	0.51	38	1.1	23	--
nm	3-T-4	5/10/64	4767I	932907	A12	--	--	--	--	--	--	--	19	0.32	6	0.8	25	--
4	3-T-5	6/10/64	4867III	071755	A13	--	--	--	--	--	--	--	156	0.47	73	1.1	31	--
5	3-T-6	6/10/64	4867III	220700	A14	--	--	--	--	--	--	--	51	--	--	2.1	14	--
4	3-T-7	6/10/64	4867III	173702	A14	--	--	--	--	--	--	--	32	--	--	2.4	15	--
nm	3-T-9	8/10/64	4767I	946963	--	--	--	--	--	--	--	--	124	0.38	47	1.4	11	--
nm	3-T-10	8/10/64	4767I	965922	--	--	--	--	--	--	--	--	93	0.62	58	2.2	15	--
5	3-T-11	9/10/64	4867IV	049832	A13	--	--	--	--	--	--	--	310	--	--	1.8	28	--
nm	3-T-12	9/10/64	4867IV	027882	A13	--	--	--	--	--	--	--	238	0.95	226	1.2	22	--
5	3-T-13	9/10/64	4867IV	145864	A13	--	--	--	--	--	--	--	158	0.92	145	1.2	22	--
4	3-T-14	9/10/64	4867III	036800	A13	--	--	--	--	--	--	--	107	0.34	36	2.5	9	--
4	3-T-15	11/10/64	4766I	964564	A15	--	--	--	--	--	--	--	118	0.64	75	--	--	--
5	3-T-16	21/10/64	4767II	956723	A15	--	--	--	--	--	--	--	120	0.45	54	3.7	21	--
5	3-T-17	21/10/64	4767II	958718	A15	--	--	--	--	--	--	--	82	0.30	25	2.0	26	--
4	3-T-18	21/10/64	4766I	879568	A15	--	--	--	--	--	--	--	398	1.20	478	1.0	22	--
nm	3-T-19	21/10/64	4766III	685392	--	--	--	--	--	--	--	--	169	0.74	125	3.2	25	--
nm	3-T-20	21/10/64	4766III	670326	--	--	--	--	--	--	--	--	287	0.53	152	1.8	22	--
nm	3-T-21	21/10/64	4766III	673283	--	--	--	--	--	--	--	--	155	0.65	101	2.2	20	--
4	3-T-22	22/10/64	4867III	060732	A13	--	--	--	--	--	--	--	170	0.59	100	1.0	30	--
8	3-T-23	22/10/64	4867III	063707	A14	--	--	--	--	--	--	--	265	0.88	233	0.6	23	--
8	3-T-24	22/10/64	4867III	025674	A14	--	--	--	--	--	--	--	147	0.75	110	1.2	23	--
nm	3-T-25	22/10/64	4866IV	022536	--	--	--	--	--	--	--	--	160	0.80	128	2.0	27	--
nm	3-T-26	22/10/64	4866IV	057527	--	--	--	--	--	--	--	--	153	0.23	35	0.2	28	--
nm	3-T-27	22/10/64	4866IV	129456	--	--	--	--	--	--	--	--	196	0.69	135	0.5	37	--
nm	3-T-28	22/10/64	4766I	973498	--	--	--	--	--	--	--	--	156	0.79	123	2.0	5	--
nm	3-T-29	22/10/64	4766I	966472	--	--	--	--	--	--	--	--	179	0.63	113	0.4	24	--
nm	3-T-30	22/10/64	4766I	935475	--	--	--	--	--	--	--	--	192	0.66	127	0.3	37	--
4	3-T-31	23/10/64	4766I	959576	A15	--	--	--	--	--	--	--	159	0.53	84	0.2	39	--
nm	3-T-32	23/10/64	4766I	993544	--	--	--	--	--	--	--	--	168	0.74	124	1.8	24	--
12	3-TC-19A	11/9/64	4867IV	166867	A13	BD	0	29	--	--	NP	SM	175	0.53	93	0.7	8	16.1
11	3-TC-19B	11/9/64	4867IV	[illegible]	A13	T	0	32	--	--	NP	SM	174	0.52	90	0.9	19	19.5
5	3-TC-19C	11/9/64	4867IV	164866	A13	BF	0	37	24	13	11	SC	112	0.28	31	--	--	22.3
5	3-TC-19D	11/9/64	4867IV	163866	A13	SB	0	57	35	18	17	CL	156	0.59	92	0.0	13	22.9
12	3-TC-19E	11/9/64	4867IV	162865	A13	LS	3	33	--	--	NP	SM	197	0.86	169	0.3	15	15.1
12	3-TC-19F	11/9/64	4867IV	160864	A13	MS	2	48	--	--	NP	SM	116	0.98	114	1.1	18	13.3
nm	3-TC-20A	12/9/64	4866IV	135458	--	SB	0	13	--	--	NP	SM	118	1.01	tf‡‡	0.8	11	19.7
nm	3-TC-20B	12/9/64	4866IV	135458	--	BF	0	47	23	18	5	SM-SC	199	1.01	201	0.1	27	14.6
nm	3-TC-20C	12/9/64	4866IV	134458	--	T	0	81	34	11	13	CL	115	0.56	64	0.4	17	23.9
nm	3-TC-20D	12/9/64	4866IV	131458	--	US	7	52	16	14	2	ML	156	0.32	50	0.7	13	17.6
nm	3-TC-20E	12/9/64	4866IV	133458	--	UF	0	63	22	13	9	CL	153	0.60	92	0.0	20	16.6
nm	3-TC-20F	12/9/64	4866IV	133458	--	LS	18	49	25	17	8	SC	212	0.69	146	0.3	10	16.3
13	3-TC-21A	13/9/64	4867III	028793	A13	NL	0	46	20	17	3	SM	119	0.54	64	1.2	18	20.1
4	3-TC-21B	13/9/64	4867III	029794	A13	T	0	54	30	18	12	CL	90	0.53	48	0.5	3	27.4
4	3-TC-21C	13/9/64	4867III	029794	A13	TS	1	57	28	18	10	CL	117	0.35	41	0.1	10	21.5
4	3-TC-21D	13/9/64	4867III	030794	A13	TS	1	57	28	18	10	CL	123	0.37	46	0.6	8	25.6
4	3-TC-21E	13/9/64	4867III	031795	A13	BF	0	46	24	17	7	SM-SC	142	0.36	51	0.3	17	21.9
4	3-TC-21F	13/9/64	4867III	031795	A13	BF	0	20	--	--	NP	SM	380	0.24	91	--	--	18.8
nm	3-TC-22A	14/9/64	4866IV	014533	--	NL	4	76	31	17	14	CL	111	0.53	59	0.5	8	22.8
nm	3-TC-22B	14/9/64	4866IV	014533	--	BD	0	88	47	23	24	CL	48	0.54	26	0.4	10	33.4
nm	3-TC-22C	14/9/64	4866IV	015533	--	TS	5	78	40	21	19	CL	84	0.73	61	0.7	11	21.5
nm	3-TC-22D	14/9/64	4866IV	026531	--	BD	0	94	33	20	13	CL	226	0.29	66	1.0	5	24.1
nm	3-TC-22E	14/9/64	4866IV	027530	--	TS	1	91	34	22	12	CL	313	0.25	78	0.2	2	24.3
nm	3-TC-23A	15/9/64	4866IV	097456	--	BF	0	66	54	26	28	CH	157	0.43	68	0.5	10	33.2
nm	3-TC-23B	15/9/64	4866IV	097456	--	LS	9	68	78	35	43	CH	220	--	tf	1.2	5	37.3
nm	3-TC-23C	15/9/64	4866IV	096457	--	UF	0	63	72	35	37	MH	219	--	tf	1.2	3	31.7
nm	3-TC-23D	15/9/64	4866IV	053510	--	TS	1	75	32	19	13	CL	672+	--	tf	0.0	10	28.5
nm	3-TC-23E	15/9/64	4866IV	054509	--	TS	1	48	--	--	NP	SM	182	0.18	33	0.5	14	14.8
nm	3-TC-23F	15/9/64	4866IV	055509	--	TS	1	54	--	--	NP	ML	108	0.18	19	0.2	17	21.1
nm	3-TC-23G	15/9/64	4866IV	058507	--	TS	1	51	--	--	NP	ML	295	0.25	74	0.4	13	12.4
nm	3-TC-24A	16/9/64	4766I	856484	--	BF	0	94	42	24	18	CL	168	0.54	91	0.8	8	28.7
nm	3-TC-24B	16/9/64	4766I	855484	--	TS	2	79	27	18	9	CL	750+	--	tf	0.0	10	15.0
nm	3-TC-24C	16/9/64	4766I	855484	--	T	0	75	33	19	14	CL	130	0.69	90	0.1	14	22.6
nm	3-TC-24D	16/9/64	4766I	854483	--	NL	0	48	--	--	NP	SM	252+	1.60	403+	0.2	16	20.2

(Continued)

Note: All soil strength measurements except sheargraph measurements were made at a 15- to 30.5-cm depth. Sheargraph measurements were made at the surface.

* nm, not mapped.

** Series L708, scale 1:50,000.

† BF, bottomland flat; BD, bottomland depression; LS, lower slope; MS, middle slope; NL, natural levee; T, terrace; TS, terrace slope; SB, stream bottom; UD, upland depression; UF, upland flat; US, upper slope.

†† a_{ur} , shear strength at zero normal load.

‡ α_{ur} , ultimate angle of internal friction.

‡‡ tf, too firm.

Table A3 (Concluded)

Map Class	Site No.	Date Sampled	Location: AMS Map Sheet	Location: Grid Coords	Location: Figure No.	Topographic Position	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: c_{ur} psi	Sheargraph: ϕ_{ur} deg	Moisture Content %
4	3-TC-25A	16/9/64	47661	892573	A15	BF	0	68	33	22	11	CL	150	0.93	140	0.0	17	14.5
15	3-TC-25B	16/9/64	48661	891572	A15	TS	2	66	26	16	10	CL	136	0.67	91	1.1	12	17.0
15	3-TC-25C	16/9/64	4866I	889571	A15	T	0	32	--	--	NP	SM	93	0.81	75	0.0	23	11.7
nm	3-TC-26A	17/9/64	47671	948978	--	BF	0	51	25	12	13	CL	195	0.40	78	--	--	15.2
nm	3-TC-26B	17/9/64	47671	948978	--	T	0	62	28	18	10	CL	58	0.33	19	0.0	24	30.4
nm	3-TC-26C	17/9/64	47671	947978	--	LS	9	28	--	--	NP	SM	111	1.93	214	0.0	18	10.7
nm	3-TC-26D	17/9/64	47671	947978	--	US	9	28	--	--	NP	SM	158	3.69	583	0.6	19	10.8
nm	3-TC-26E	17/9/64	47671	947978	--	UF	0	31	--	--	NP	SM	239	--	tf**	0.6	12	11.8
11	3-TC-27A	18/9/64	47671I	962791	A12	T	0	47	19	13	6	SM-SC	173	0.32	55	0.7	12	15.6
11	3-TC-27B	18/9/64	47671I	961792	A12	LS	1	52	22	14	8	CL	356	0.65	231	0.3	17	12.4
11	3-TC-27C	18/9/64	47671I	959793	A12	LS	1	42	17	14	3	SM	420	0.35	147	0.3	13	15.3
11	3-TC-27D	18/9/64	47671I	959794	A12	NL	0	49	22	15	7	SM-SC	115	0.47	54	0.0	16	17.5
11	3-PR-80	25/7/62	4867IV	217825	A13	T	2	62	24	16	8	CL	89	0.53	47	--	--	20.1
12	3-PR-81	25/7/62	4867IV	202832	A13	UF	1	37	16	16	0	SM	146	1.00	146+	--	--	14.0
12	3-PR-82	25/7/62	4867IV	190840	A13	MS	35	42	22	14	8	SC	103	0.51	53	--	--	15.9
12	3-PR-83	25/7/62	4867IV	188843	A13	MS	6	14	21	15	6	SM-SC	301	1.00	301+	--	--	10.3
13	3-PR-84	25/7/62	4867IV	130856	A13	NL	0	88	40	24	16	CL	132	0.78	103	--	--	23.8
4	3-PR-85	25/7/62	4867IV	130855	A13	BD	0	77	41	24	17	CL	80	0.60	48	--	--	23.8
4	3-PR-96	28/7/62	47661	892577	A15	BF	0	55	26	15	11	CL	95	0.58	55	--	--	23.6
5	3-PR-97	29/7/62	47671I	917686	A15	T	1	53	23	16	7	CL-ML	140	--	--	--	--	11.1
11	3-PR-98	29/7/62	47671I	962792	A12	T	1	53	19	12	7	CL-ML	171	1.00	171+	--	--	11.8
12	3-PR-99	29/7/62	47671	965840	A12	MS	35	68	57	30	27	MH	118	0.71	84	--	--	30.6

** tf, too firm.

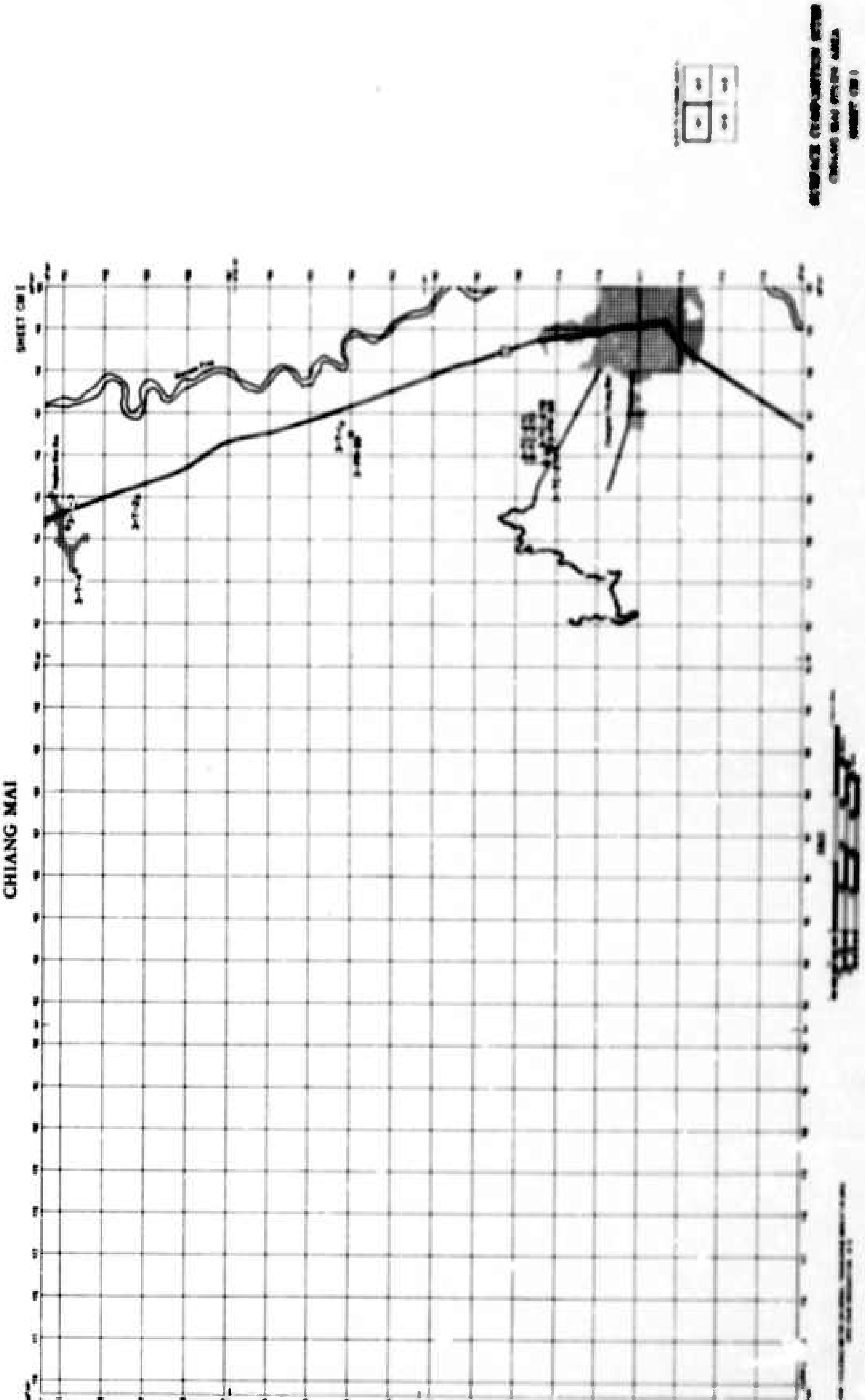


FIG. A12

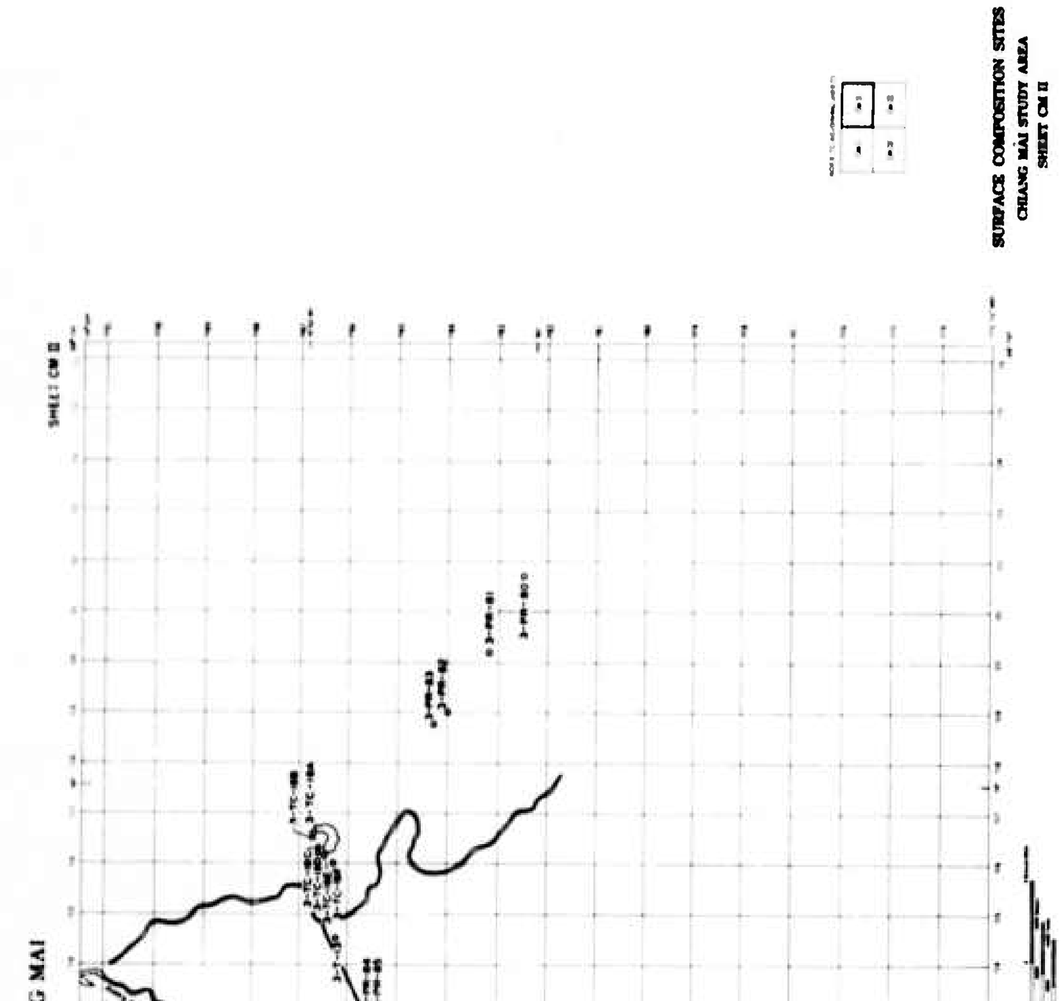
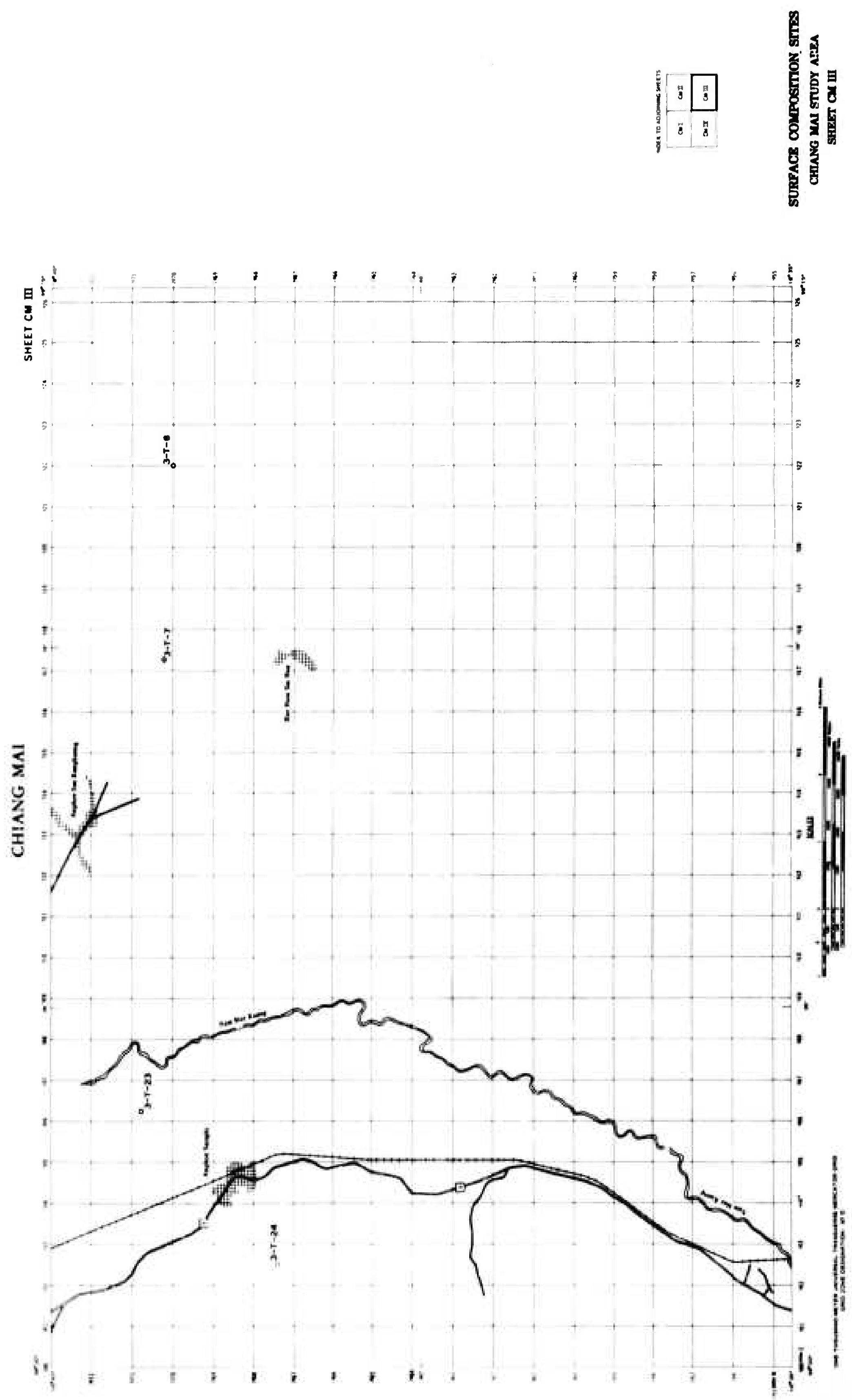

CHIANG MAI
SURFACE COMPOSITION SITES
CHIANG MAI STUDY AREA
SHEET CM II

FIG. A13



SURFACE COMPOSITION SITES
CHIANG MAI STUDY AREA
SHEET CM III
SHEET CM III
CHIANG MAI
3-T-8
3-T-7
3-T-23
3-T-24

A25

FIG. A14

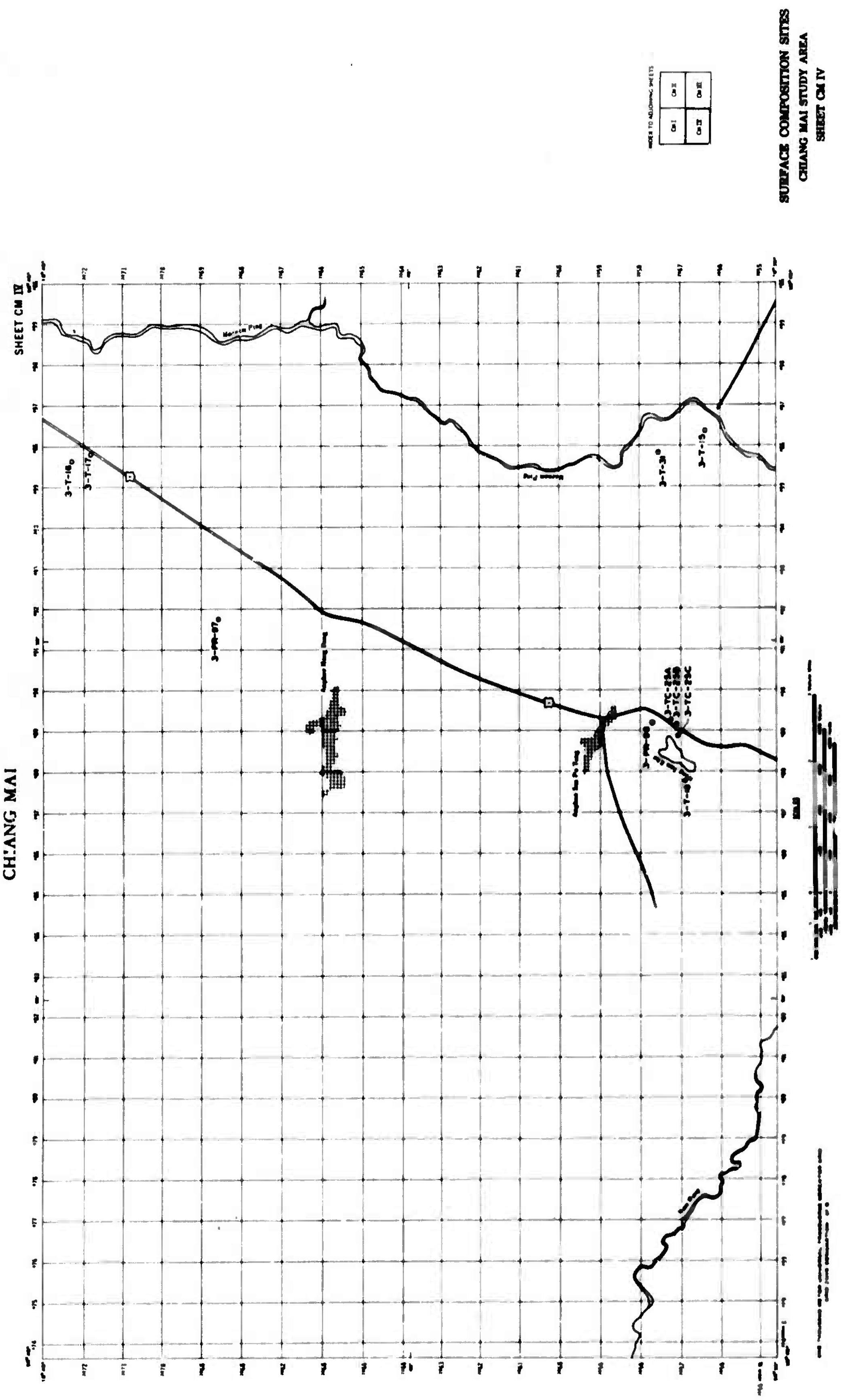

CHIANG MAI
SHEET CM IV
SURFACE COMPOSITION SITES
CHIANG MAI STUDY AREA
SHEET CM IV

FIG. A15 A26

PRAN BURI STUDY AREA

BLANK PAGE

Table A4

Summary of Surface Composition Field Data

Pran Buri

Map Class*	Site No.	Date Sampled	Location: AMS Map Sheet**	Location: Grid Coords	Location: Figure No.	Topographic Position†	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: a_{ur}†† psi	Sheargraph: α_{ur}‡	Moisture Content %
1	4-T-1	15/4/65	49471	991506	A18	BF	1	--	--	--	--	--	31	0.68	21	--	--	--
1	4-T-2	15/4/65	4947I	994502	A18	BF	1	--	--	--	--	--	27	0.67	18	--	--	--
2	4-T-3	15/4/65	4947I	008489	A18	BF	1	--	--	--	--	--	82	1.17	96	--	--	--
1	4-T-4	17/4/65	4947I	977463	A18	BF	1	--	--	--	--	--	74	0.82	61	--	--	--
1	4-T-5	17/4/65	4947II	982446	A18	BF	1	--	--	--	--	--	53	0.81	43	--	--	43.2
1	4-T-6	18/4/65	4947I	973451	A18	BF	1	--	--	--	--	--	58	0.79	46	--	--	38.6
1	4-T-7	18/4/65	4947II	970446	A18	BF	1	--	--	--	--	--	45	0.51	23	--	--	58.6
1	4-T-8	19/4/65	4947II	969439	A18	BF	1	--	--	--	--	--	43	0.53	23	--	--	--
1	4-T-9	19/4/65	4947II	969427	A18	BF	1	--	--	--	--	--	32	0.75	24	--	--	--
1	4-T-10	20/4/65	4947II	984425	A18	BF	1	--	--	--	--	--	54	0.81	44	--	--	--
2	4-T-11	20/4/65	49471	011526	A18	BF	1	--	--	--	--	--	77	0.77	59	--	--	--
2	4-T-12	20/4/65	49471	018556	A17	BF	1	--	--	--	--	--	48	0.92	44	--	--	49.6
1	4-T-13	21/4/65	49471	996512	A18	NL	1	--	--	--	--	--	37	--	--	--	--	--
6	4-T-14	22/4/65	4947I	997567	A17	BF	1	--	--	--	--	--	83	0.64	53	--	--	--
1	4-T-15	22/4/65	4947I	986556	A17	BF	1	--	--	--	--	--	77	0.55	42	--	--	--
1	4-T-16	22/4/65	4947I	001554	A17	NL	1	--	--	--	--	--	46	0.70	32	--	--	--
1	4-T-17	23/4/65	4947I	977481	A18	BF	1	--	--	--	--	--	69	0.77	53	--	--	54.9
1	4-T-18	23/4/65	4947II	993446	A18	BD	1	--	--	--	--	--	46	1.09	50	--	--	--
15	4-T-19	24/4/65	4948II	909746	A16	NL	1	--	--	--	--	--	671	--	tf‡‡	--	--	13.6
5	4-T-20	24/4/65	4948II	901741	A16	BF	1	--	--	--	--	--	730+	--	tf	0.0	24	9.4
15	4-T-21	24/4/65	4948II	904778	A16	BF	1	--	--	--	--	--	640	--	tf	1.9	15	4.5
nm	4-T-22	24/4/65	--	--	--	BF	1	--	--	--	--	--	750+	--	tf	0.0	23	5.7
15	4-T-23	25/4/65	4948II	879752	A16	BF	1	--	--	--	--	--	750+	--	tf	0.0	31	3.6
15	4-T-24	25/4/65	4948II	862776	A16	BF	1	--	--	--	--	--	750+	--	tf	0.0	38	3.7
15	4-T-25	25/4/65	494811	837739	A16	NL	1	--	--	--	--	--	750+	--	tf	0.0	38	5.9
15	4-T-26	25/4/65	4948II	945745	A16	BF	1	--	--	--	--	--	750+	--	tf	0.0	38	5.6
15	4-T-27	26/4/65	4947I	056578	A17	BD	1	--	--	--	--	--	750+	--	tf	0.2	46	12.9
8	4-T-28	26/4/65	4947I	054562	A17	BF	1	--	--	--	--	--	750+	--	tf	0.0	48	15.1
6	4-T-29	27/4/65	4947I	986530	A18	BF	1	--	--	--	--	--	113	0.69	78	--	--	28.7
6	4-T-30	27/4/65	4947I	982522	A18	BF	I	--	--	--	--	--	92	0.68	63	1.5	41	50.4
15	4-T-31	28/4/65	4948II	929750	A16	BF	1	--	--	--	--	--	750+	--	tf	--	--	5.4
15	4-T-32	28/4/65	4948II	918744	A16	BF	1	--	--	--	--	--	750+	--	tf	0.0	44	12.7
5	4-T-33	28/4/65	4948II	908723	A17	BF	1	--	--	--	--	--	328	--	tf	0.0	39	10.8
5	4-TC-38A	4/10/64	4947I	943509	A18	SB	0	--	--	--	--	CL	172	0.67	115	0.8	17	18.5
5	4-TC-38B	4/10/64	4947I	943508	A18	TS	0	--	--	--	--	CL	95	0.76	72	0.0	22	14.4
5	4-TC-38C	4/10/64	49471	943508	A18	TS	3	--	--	--	--	CL-ML	118	0.74	87	0.0	17	14.1
5	4-TC-38D	4/10/64	49471	943507	A18	T	0	--	--	--	--	CL-ML	73	0.45	33	0.0	16	[illegible]
5	4-TC-39A	4/10/64	4947I	937585	A17	T	0	--	--	--	--	ML	49	0.22	11	0.2	18	20.2
5	4-TC-39B	4/10/64	4947I	937585	A17	[illegible]	6	--	--	--	--	ML	106	0.37	39	0.0	20	16.2
5	4-TC-39C	4/10/64	49471	936586	A17	LS	6	--	--	--	--	CL	85	0.84	71	0.0	23	15.1
5	4-TC-39D	4/10/64	4947I	936586	A17	MS	10	--	--	--	--	ML	79	0.81	64	0.0	22	13.3
15	4-TC-40A	5/10/64	4948II	046693	A17	NL	1	--	--	--	--	SM	143	--	--	0.2	21	17.4
15	4-TC-40B	5/10/64	4948II	046693	A17	NL	1	--	--	--	--	CL	155	0.67	104	0.6	18	23.6
15	4-TC-40C	5/10/64	4948II	046692	A17	T	0	--	--	--	--	CL	345	--	--	0.3	25	16.5
8	4-TC-40D	5/10/64	494811	045691	A17	BF	0	--	--	--	--	CL	91	0.48	44	0.2	17	28.0
8	4-TC-41A	5/10/64	4948I	049853	A16	TS	1	--	--	--	--	CL	199	--	--	0.0	26	18.3
8	4-TC-41B	5/10/64	4948I	050850	A16	TS	0.5	--	--	--	--	CL	264	--	--	0.0	26	16.0
8	4-TC-41C	5/10/64	4948I	052847	A16	TS	0.5	--	--	--	--	CL	185	0.58	107	0.7	15	21.0
15	4-TC-41D	5/10/64	49481	053844	A16	TS	1	--	--	--	--	CL	293	--	--	0.9	15	15.9
nm	4-TC-42A	6/10/64	4949II	038059	--	T	0	--	--	--	--	SM	518	--	--	0.4	10	8.5
nm	4-TC-42B	6/10/64	4949II	038062	--	T	0	--	--	--	--	SC	482	--	--	0.8	10	6.6
nm	4-TC-42C	6/10/64	4949II	039066	--	T	0	--	--	--	--	SM	668	--	--	0.0	18	9.0
nm	4-TC-42D	6/10/64	4949II	040069	--	T	0	--	--	--	--	CL-ML	567	--	--	0.2	9	12.7
nm	4-TC-43A	6/10/64	4949II	036010	--	T	0	--	--	--	--	SM	472+	--	--	0.2	16	9.0
nm	4-TC-43B	6/10/64	4949II	036013	--	T	0	--	--	--	--	SM	224	--	--	0.7	20	7.2
nm	4-TC-43C	6/10/64	4949II	036017	--	T	0	--	--	--	--	CL-ML	112	0.45	50	0.6	13	15.0
nm	4-TC-43D	6/10/64	494911	037030	--	T	0	--	--	--	--	CL-ML	713	--	--	0.0	18	13.3
nm	4-TC-44A	7/10/64	4949II	045156	--	BF	0	--	--	--	--	CL	159	0.84	134	--	--	22.2
nm	4-TC-44B	7/10/64	494911	043156	--	TS	1	--	--	--	--	CL-ML	244	0.40	98	0.0	11	18.3
nm	4-TC-44C	7/10/64	4949II	041156	--	TS	1	--	--	--	--	CL	348	0.53	184	0.0	21	17.5
nm	4-TC-44D	7/10/64	4949II	040155	--	TS	1	--	--	--	--	CL	269	--	--	0.3	21	15.4
nm	4-TC-44E	7/10/64	4949II	039155	--	T	0	--	--	--	--	CL-ML	236	0.67	158	0.2	20	11.7
nm	4-TC-44F	7/10/64	4949II	037155	--	T	0	--	--	--	--	CL	143	0.47	67	--	--	18.8
nm	4-TC-45A	8/10/64	4949II	072143	--	B	13	--	--	--	--	SP	250	2.04	510	0.0	18	20.3
nm	4-TC-45B	8/10/64	4949II	072143	--	B	0	--	--	--	--	SP	190	1.40	266	0.6	3	5.0
nm	4-TC-45C	8/10/64	4949II	071144	--	T	0	--	--	--	--	SP	243	0.78	190	0.0	17	3.0
nm	4-TC-46A	8/10/64	494911	072144	--	B	13	--	--	--	--	SP	218	1.50	327	0.3	8	21.7
nm	4-TC-46B	8/10/64	4949II	072144	--	B	0	--	--	--	--	SP	187	1.65	309	0.2	3	3.5
nm	4-TC-46C	8/10/64	4949II	071144	--	T	0	--	--	--	--	SP	283	0.82	232	0.8	8	2.5
nm	4-TC-47A	8/10/64	4949II	063146	--	T	0	--	--	--	--	CH	336	1.03	346	0.5	20	19.1
nm	4-TC-47B	8/10/64	4949II	063148	--	T	0	--	--	--	--	CL	310	--	--	--	--	22.5
nm	4-TC-48A	9/10/64	4948I	041960	--	B	12	--	--	--	--	SP	286	--	--	0.0	20	14.7
nm	4-TC-48B	9/10/64	49481	041961	--	B	8	--	--	--	--	SP	170	--	--	--	--	3.1
nm	4-TC-48C	9/10/64	4948I	040961	--	TS	3	--	--	--	--	SP-SM	431	--	--	1.7	13	4.6
nm	4-TC-48D	9/10/64	49481	038961	--	TS	1	--	--	--	--	SM	548	--	--	0.0	20	6.8

Note: All soil strength measurements except sheargraph measurements were made at a 15- to 30.5-cm depth. Sheargraph measurements were made et the surface.

* nm, not mapped.

** Series L708, scale 1:50,000.

† BF, bottomland flat; BD, bottomland depression; LS, lower slope; MS, middle slope; NL, natural levee; T, terrace; TS, terrace slope; SB, stream bottom; UD, upland depression; UF, upland flat; US, upper slope.

†† a_{ur}, shear strength at zero normal load.

‡ α_{ur}, ultimate angle of internal friction.

‡‡ tf, too firm.

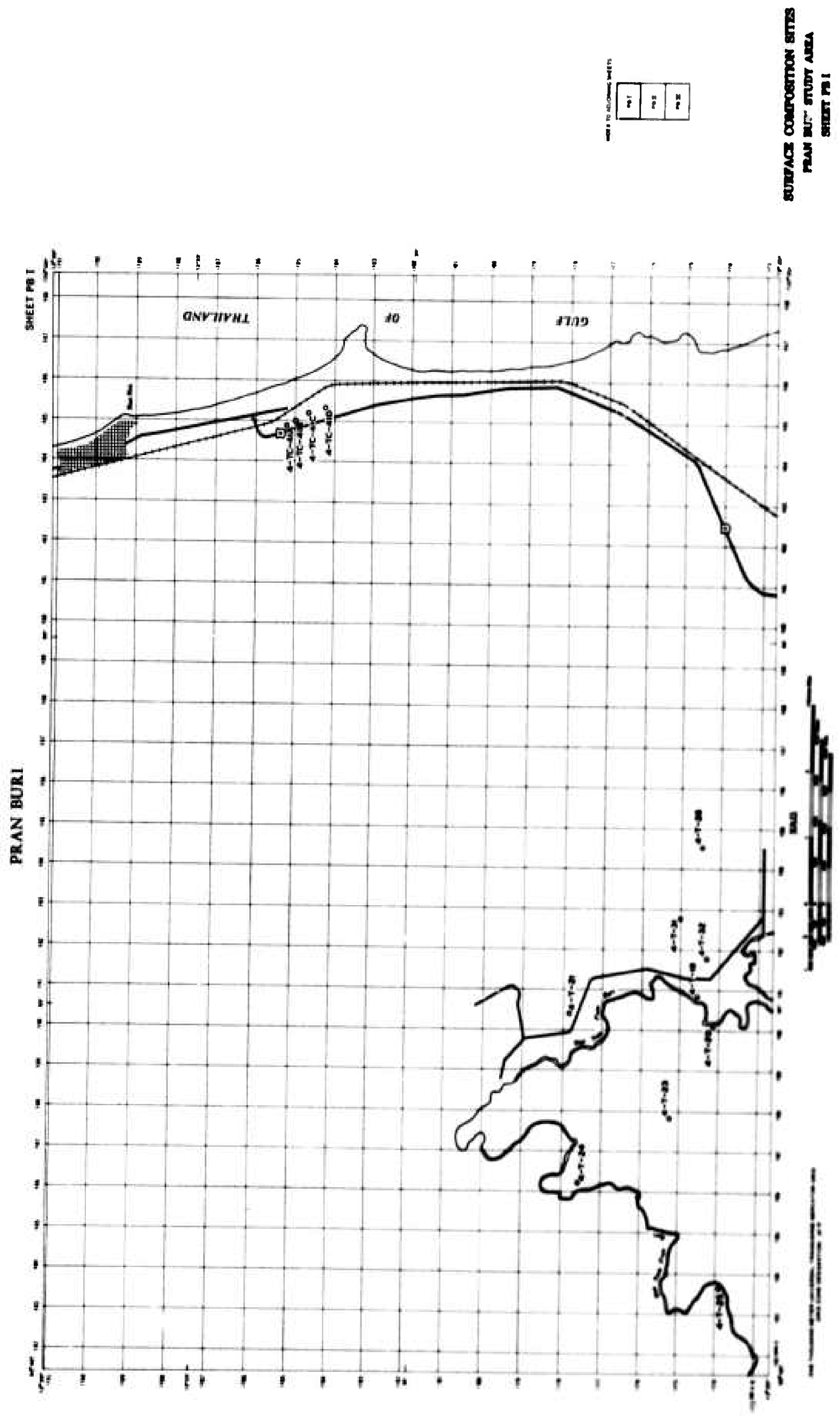

SURFACE COMPOSITION SITES
SHEET PB I
PRAN BURI
SHEET PB I
GULF
OF
THAILAND

FIG. A16

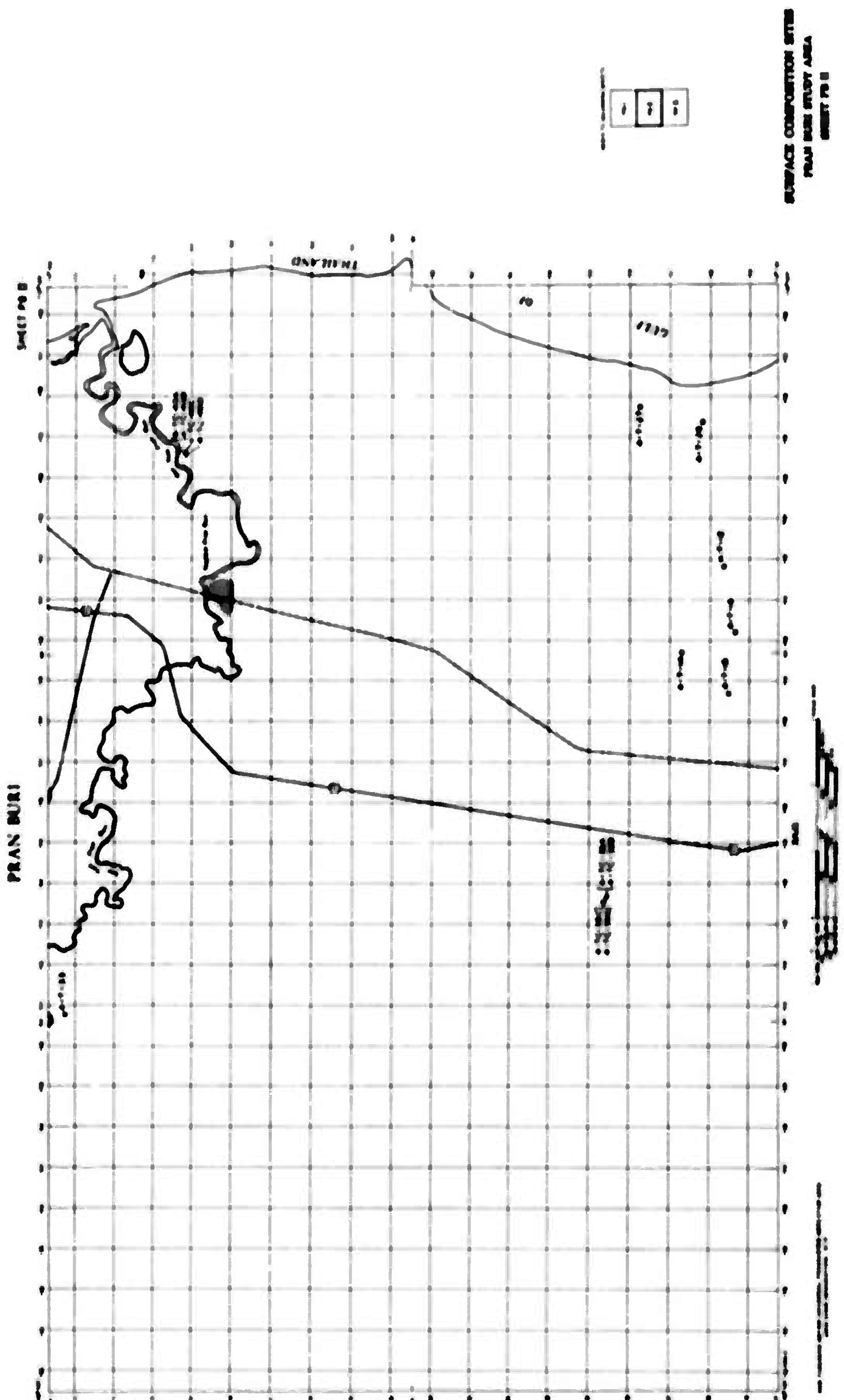


FIG. A17

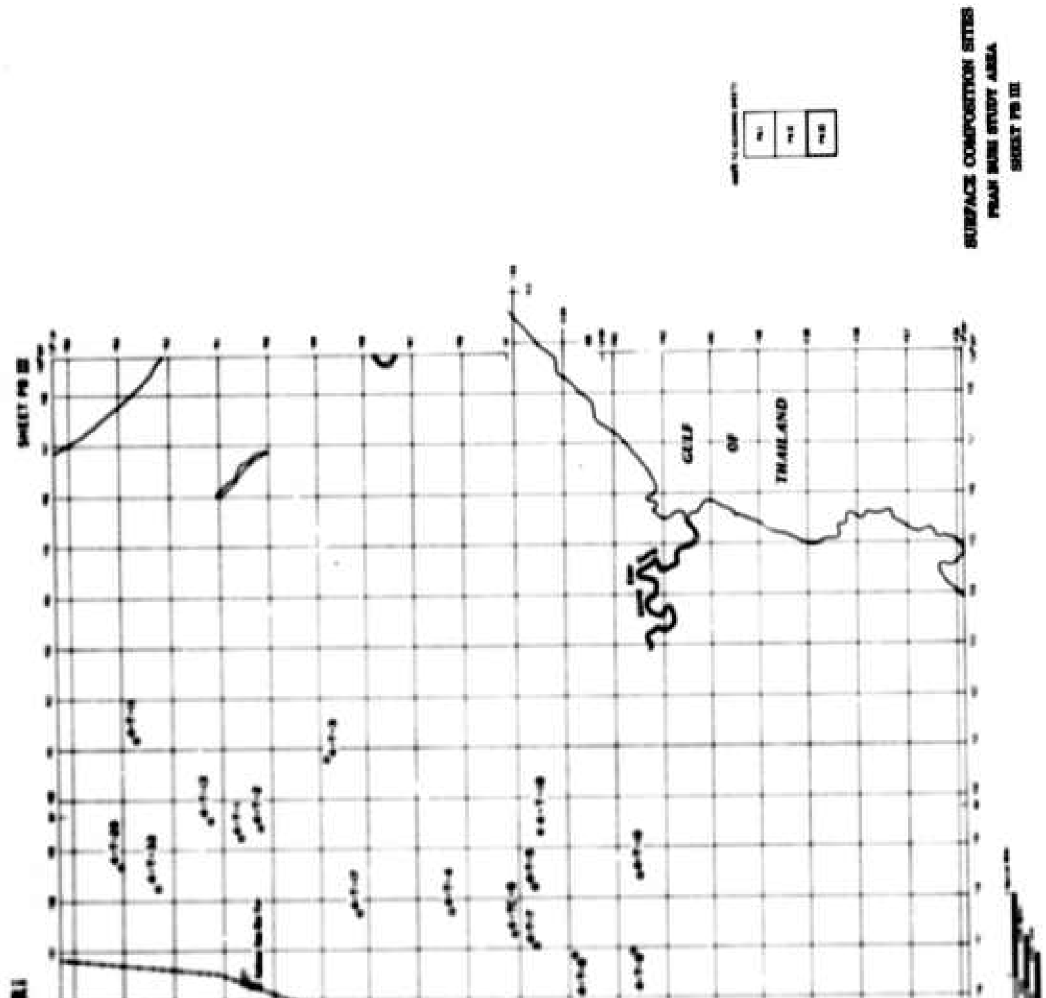

SURFACE COMPOSITION SITES
PRAN BURI STUDY AREA
SHEET PB III
PRAN BURI
GULF
OF
THAILAND

FIG. A18

KHON KAEN STUDY AREA

BLANK PAGE

Table A5

Summary of Surface Composition Field Data

Khon Kaen

Map Class*	Site No.	Date Sampled	Location: AMS Map Sheet**	Location: Grid Coords	Location: Figure No.	Topographic Position†	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: a_{ur}†† psi	Sheargraph: α_{ur}‡ deg	Moisture Content %
4	5-T-1	18/11/64	5560II	733470	A20	--	--	75	28	17	11	CL	106	0.61	[illegible]	[illegible]	[illegible]	[illegible]
8	5-T-2	18/11/64	5560II	766184	A20	--	--	90	79	47	32	MH	108	1.19	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-3	18/11/64	5560II	805180	A21	--	--	79	69	32	37	CH	211	1.15	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-4	16/11/64	5560II	806259	A21	--	--	11	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-5	16/11/64	5560II	810245	A21	--	--	63	--	--	NP	[illegible]	300+	--	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-6	16/11/64	5560I	827257	--	--	--	22	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-7	18/11/64	5560I	850277	--	--	--	29	26	14	12	SC	[illegible]	0.77	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-8	19/11/64	5560II	735148	A20	--	--	80	25	17	8	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-9	19/11/64	5660III	907186	A21	--	--	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-10	19/11/64	5660III	913170	A21	--	--	11	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-11	20/11/64	5560II	718018	A20	--	--	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-12	20/11/64	5560II	730747	A20	--	--	68	33	23	10	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-13	20/11/64	5560II	610055	A20	--	--	66	38	20	18	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-14	20/11/64	5560II	660152	A20	--	--	68	31	17	14	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-15	23/11/64	5461II	160453	--	--	--	[illegible]	--	--	NP	SM	213	0.79	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-16	23/11/64	5461II	125460	--	--	--	58	--	--	NP	ML	173	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	5-T-17	24/11/64	5560II	665090	A20	--	--	41	25	16	9	SC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-18	25/11/64	5560II	667044	A20	--	--	45	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-19	11/12/64	5460I	237277	--	--	--	93	73	[illegible]	[illegible]	CH	71	1.39	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-20	11/12/64	5460I	236287	--	--	--	[illegible]	30	14	16	CL	107	1.43	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-21	11/12/64	5460I	234344	--	--	--	44	24	18	6	SM-SC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-22	11/12/64	5460I	283324	--	--	--	64	29	14	15	CL	150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-23	12/12/64	5460I	163335	--	--	--	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-24	12/12/64	5460I	143363	--	--	--	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-25	12/12/64	5460II	188253	--	--	--	[illegible]	41	29	12	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-26	12/12/64	5560II	293240	A19	--	--	52	21	18	3	ML	153	0.58	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-T-27	13/12/64	5461III	990485	--	--	--	48	19	-	NP	SM	175	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-28	13/12/64	5460II	266190	A19	--	--	67	26	16	10	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-29	14/12/64	5560III	[illegible]	A20	--	--	60	--	--	NP	ML	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-30	14/12/64	5560III	375025	A19	--	--	59	18	18	0	ML	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-31	14/12/64	5560III	377173	A19	--	--	[illegible]	27	18	9	CL	71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-32	14/12/64	5560III	504145	A19	--	--	[illegible]	--	--	NP	SM	240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-33	15/12/64	5560III	563137	A20	--	--	[illegible]	--	--	NP	SM	300+	--	[illegible]	[illegible]	[illegible]	[illegible]
5	5-T-34	15/12/64	5560III	515237	A20	--	--	[illegible]	13	13	0	ML	[illegible]	0.79	[illegible]	[illegible]	[illegible]	[illegible]
11	5-T-35	15/12/64	5560III	560237	A20	--	--	[illegible]	--	--	NP	SM	300+	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-40	31/3/65	5560II	797160	A21	LS	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-41	31/3/65	5560II	[illegible]	A21	NL	2	--	--	-	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-42	31/3/65	5560II	[illegible]	A21	BF	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-43	1/4/65	5560II	798156	A21	BF	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-44	1/4/65	5560II	794152	A21	BF	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
15	5-T-45	1/4/65	5560II	798150	A21	BF	1	--	--	--	--	--	750+	--	[illegible]	[illegible]	[illegible]	[illegible]
8	5-T-46	2/4/65	5560II	[illegible]	A20	BF	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
8	5-T-47	2/4/65	5560II	759037	A20	BF	1	--	--	--	--	--	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-48	2/4/65	5560II	731240	A20	BF	1	--	--	--	--	--	750+	--	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-49	2/4/65	5560II	730737	A20	BF	1	--	--	--	--	--	750+	--	[illegible]	[illegible]	[illegible]	[illegible]
4	5-T-50	2/4/65	5560II	760031	A20	BF	1	--	--	--	--	--	750+	--	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-49A	15/10/64	5460I	200433	--	T	0	[illegible]	24	16	8	SC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-49B	15/10/64	5460I	202432	--	LS	3	[illegible]	34	17	17	SC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-49C	15/10/64	5460I	203431	--	MS	2	45	16	15	1	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-49D	15/10/64	5460I	204429	--	UF	0	35	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-50A	15/10/64	5460I	235363	--	SB	0	5	--	--	NP	SP-SM	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]
nm	5-TC-50B	15/10/64	5460I	235362	--	LS	3	23	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-50C	15/10/64	5460I	236361	--	US	2	25	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-50D	15/10/64	5460I	237358	--	UF	0	26	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-51A	16/10/64	5560I	673366	--	T	0	43	18	16	2	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-51B	16/10/64	5560I	674365	--	LS	4	28	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-51C	16/10/64	5560I	675363	--	US	3	36	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-51D	16/10/64	5560I	676364	--	UF	0	27	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-52A	16/10/64	5560I	687088	--	TS	1	[illegible]	29	17	12	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-52B	16/10/64	5560I	688085	--	TS	2	[illegible]	30	16	14	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-52C	16/10/64	5560I	689081	--	TS	2	70	24	18	6	CL-ML	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
nm	5-TC-52D	16/10/64	5560I	689079	--	T	0	56	16	--	NP	ML	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-TC-53A	17/10/64	5560III	425232	A19	T	0	52	34	17	17	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-53B	17/10/64	5560III	427231	A19	LS	4	37	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-53C	17/10/64	5560III	428231	A19	US	4	35	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-53D	17/10/64	5560III	429231	A19	UF	0	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-53E	17/10/64	5560III	429230	A19	UF	0	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-TC-54A	17/10/64	5560III	534198	A20	TS	2	[illegible]	37	16	21	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-TC-54B	17/10/64	5560III	530198	A20	TS	1	57	30	14	[illegible]	CL	[illegible]	[illegible]	[illegible]	--	--	[illegible]
5	5-TC-5[illegible]	17/10/64	5560III	529197	A20	TS	1.5	[illegible]	16	15		SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	5-TC-54D	17/10/64	5560III	527196	A20	T	0	33	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-55A	17/10/64	5560III	903187	A21	BF	0	30	--	--	NP	SM	[illegible]	[illegible]	[illegible]	--	--	[illegible]
11	5-TC-55B	17/10/64	5560III	907188	A21	TS	3	[illegible]	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-TC-55C	17/10/64	5560III	905188	A21	TS	2	31	--	--	NP	SM	[illegible]	--	--	[illegible]	[illegible]	[illegible]
11	5-TC-55D	17/10/64	5560III	904189	A21	TS	2	37	--	--	NP	SM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-TC-56A	18/10/64	5560II	749173	A20	TS	1	[illegible]	32	17	15	CL	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]
4	5-TC-56B	18/10/64	5560II	748173	A20	T	0	[illegible]	32	17	15	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-TC-56C	18/10/64	5560II	748170	A20	T	0	66	29	18	11	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	5-TC-56D	18/10/64	5560II	747172	A20	TS	1	64	27	17	10	CL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	5-PR-56	2/7/62	5560II	685231	A20	MS	1	[illegible]	13	13	0	ML	[illegible]	1.00	[illegible]	--	--	[illegible]

Note: All soil strength measurements except sheargraph measurements were made at a 15- to 30.5-cm depth. Sheargraph measurements were made at the surface.

* nm, not mapped.

** Series L708, scale 1:50,000.

† BF, bottomland flat; BD, bottomland depression; LS, lower slope; MS, middle slope; NL, natural levee, T, terrace; TS, terrace slope; SB, stream bottom; UD, upland depression; UF, upland flat; US, upper slope.

†† a_{ur} , shear strength at zero normal load.

‡ α_{ur} , ultimate angle of internal friction.

‡‡ tf, too firm.

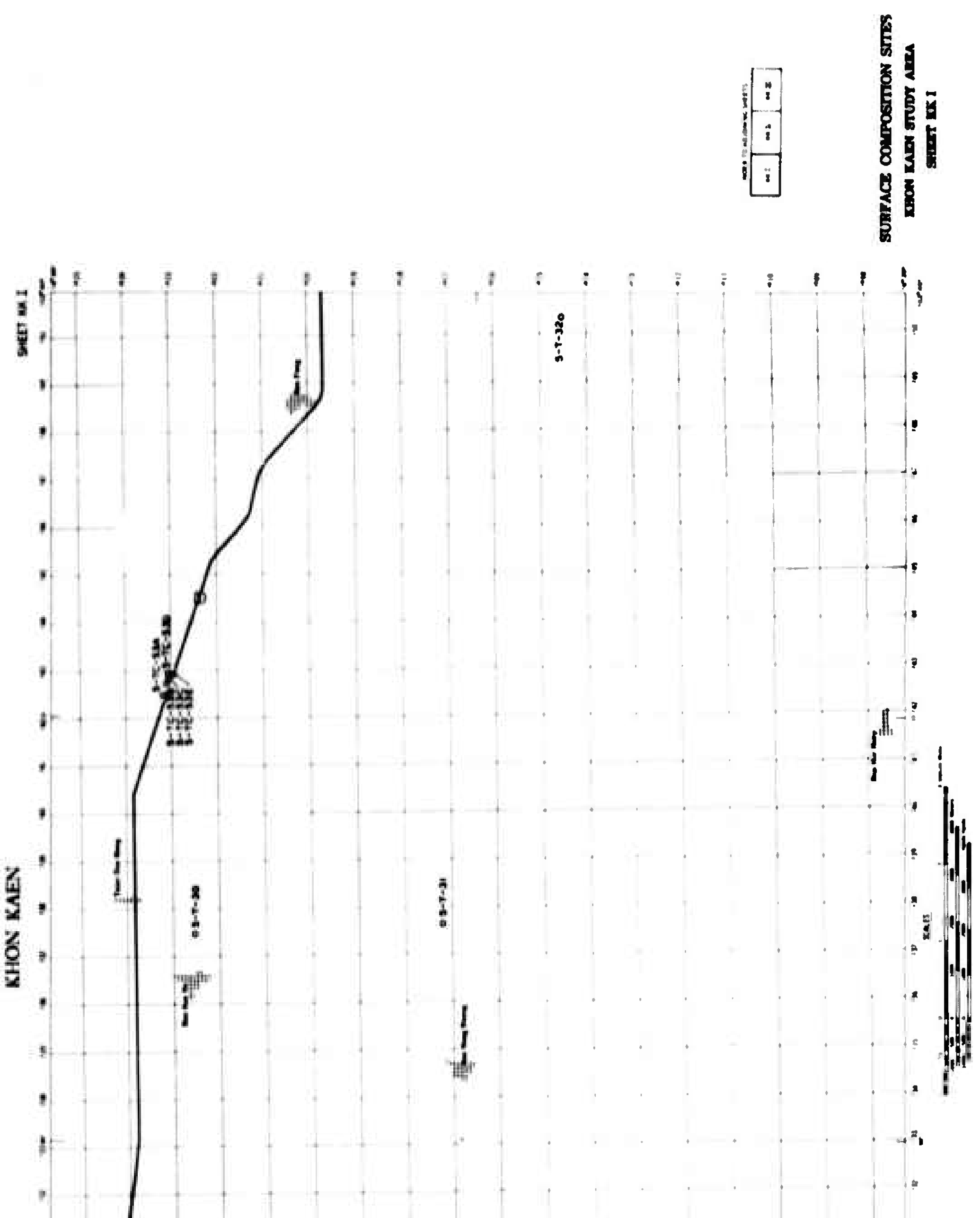

KHON KAEN
SHEET KK I
SURFACE COMPOSITION SITES
KHON KAEN STUDY AREA
SHEET KK I

FIG. A19

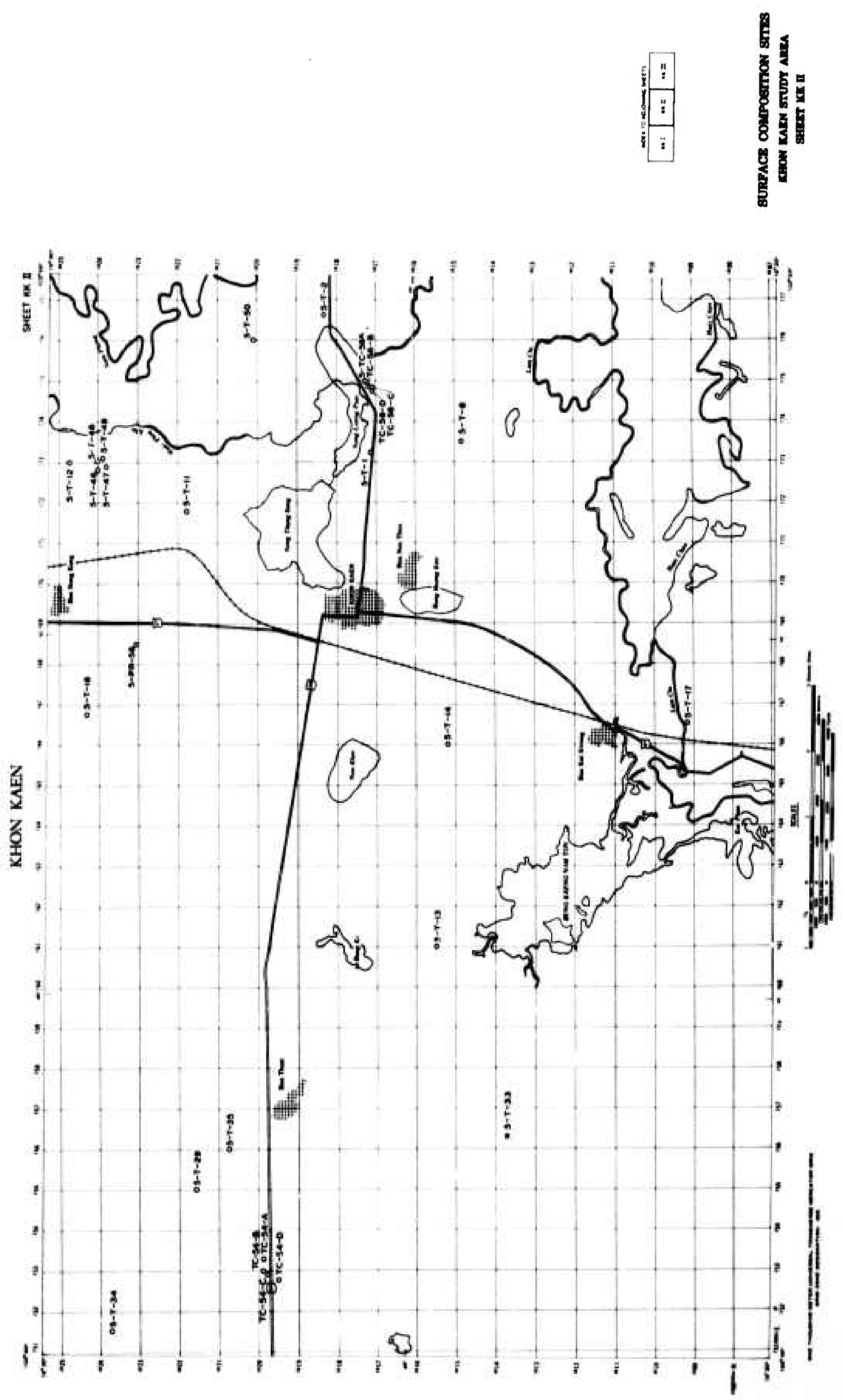

KHON KAEN
SHEET KK II
SURFACE COMPOSITION SITES
KHON KAEN STUDY AREA
SHEET KK II

FIG. A20

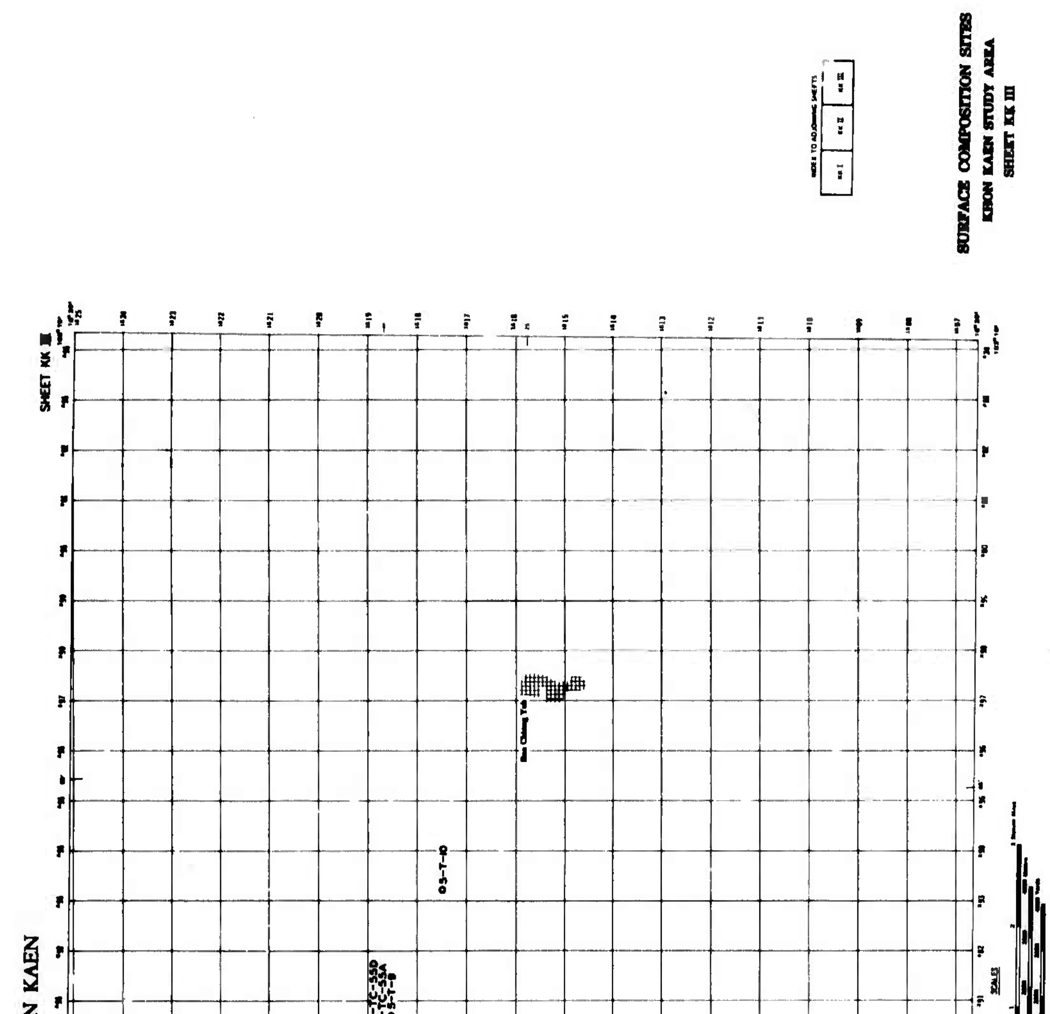

SURFACE COMPOSITION SITES
KHON KAEN STUDY AREA
SHEET KK III
KHON KAEN
SHEET KK III
SCALES
0 3-T-5
3-T-4
3-T-3
0 3-T-10
0 3-T-9
3-T-40
3-T-41
0 3-T-42
0 3-T-43
3-T-44
3-T-45

FIG. A21

CHANTHABURI STUDY AREA

BLANK PAGE

Table A6

Summary of Surface Composition Field Data

Chanthaburi

Map Class*	Site No.	Date Sampled	Location: AMS Map Sheet**	Location: Grid Coords	Location: Figure No.	Topographic Position†	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: a_{ur} †† psi	Sheargraph: α_{ur} ‡ deg	Moisture Content %
1	6-TC-28A	23/9/64	5448IV	889951	A24	TS	2	54	32	14	18	CL	153	0.54	83	0.5	13	18.2
1	6-TC-28B	23/9/64	5448IV	889952	A24	TS	2	52	24	15	9	CL	112	0.68	76	0 0	13	17.2
1	6-TC-28C	23/9/64	5448IV	889952	A24	TS	2	51	25	16	9	CL	147	0.50	74	0.2	13	19.4
nm	6-TC-28D	23/9/64	5448IV	889953	A24	T	0	58	28	17	11	CL	145	0.54	78	0.2	14	18.8
nm	6-TC-29A	23/9/64	5448IV	840993	A24	BF	0	67	44	24	20	CL	93	0.38	35	0.0	7	37.6
nm	6-TC-29B	23/9/64	5448IV	838932	A24	BF	0	78	88	33	55	CH	47	0.51	24	--	--	93.8
nm	6-TC-29C	23/9/64	5448IV	841934	A24	BF	0	78	34	17	17	CL	88	0.48	42	0.6	9	31.5
nm	6-TC-30A	24/9/64	5448IV	759003	A24	NL	0	58	28	16	12	CL	103	0.49	50	0.2	10	21.5
nm	6-TC-30B	24/9/64	5448IV	758004	A24	TS	2	48	23	15	8	SC	50	0.64	32	0.2	10	20.5
nm	6-TC-30C	24/9/64	5448IV	758005	A24	TS	2	41	17	12	5	SM-SC	91	0.46	42	0.0	15	16.7
nm	6-TC-30D	24/9/64	5448IV	758006	A24	T	0	51	23	14	9	CL	99	0.54	53	0.2	13	19.1
nm	6-TC-31A	24/9/64	5339II	213078	A22	NL	5	76	41	25	16	CL	69	0.52	36	0.2	16	32.3
nm	6-TC-31B	24/9/64	5339II	213078	A22	BF	0	93	65	33	32	MH	63	0.68	43	1.1	6	41.3
nm	6-TC-31C	24/9/64	5339II	212078	A22	BD	0	94	55	28	27	CH	49	0.61	30	--	--	38.3
nm	6-TC-32A	25/9/64	5339II	141101	A22	T	0	49	--	--	NP	SM	109	0.07	8	0.0	21	22.3
nm	6-TC-32B	25/9/64	5339II	141101	A22	LS	8	49	12	--	NP	SM	115	0.36	41	0.0	18	16.6
nm	6-TC-32C	25/9/64	5339II	141102	A22	MS	10	61	27	16	11	CL	96	0.51	49	0.9	12	18.9
nm	6-TC-32D	25/9/64	5339II	141102	A22	US	11	61	24	14	10	CL	124	0.52	64	0.8	14	17.5
nm	6-TC-33A	25/9/64	5448IV	759001	A24	BD	0	92	53	33	20	MH	199	0.29	58	0.0	17	42.5
nm	6-TC-33B	25/9/64	5448IV	761000	A24	TS	3	87	56	43	13	MH	326	--	tf‡‡	0.0	19	41.7
nm	6-TC-33C	25/9/64	5448IV	762999	--	T	0	86	--	--	--	MH	79	0.68	54	0.0	20	43.3
nm	6-TC-34A	26/9/64	5349III	951136	--	NL	0	88	--	--	--	ML	114	0.54	62	0.7	4	30.3
nm	6-TC-34B	26/9/64	5349III	951137	--	TS	1	60	--	--	--	ML	112	0.59	66	0.2	15	19.9
nm	6-TC-34C	26/9/64	5349III	950138	--	TS	4	42	48	24	24	SC	186	0.83	154	0.8	14	17.7
nm	6-TC-34D	26/9/64	5349III	950139	--	TS	3	42	36	19	17	SC	583+	0.55	321+	0.7	19	18.8
nm	6-TC-34E	26/9/64	5349III	949139	--	LS	5	58	36	22	14	CL	686+	--	tf	0.8	17	21.4
nm	6-TC-35A	27/9/64	5349III	743027	--	BF	0	70	22	15	7	CL-ML	81	0.35	28	0.5	20	20.2
nm	6-TC-35B	27/9/64	5349III	743028	--	TS	4	67	26	13	13	CL	105	0.73	77	0.0	17	17.7
nm	6-TC-35C	27/9/64	5349III	743028	--	T	0	52	12	12	0	ML	119	0.48	57	0.2	20	16.7
nm	6-TC-35D	27/9/64	5349III	742028	--	LS	5	45	14	--	NP	SM	114	1.28	146	0.3	15	16.0
nm	6-TC-35E	27/9/64	5349III	742029	--	MS	10	66	26	16	10	CL	115	0.60	69	1.0	20	18.6
nm	6-TC-36A	28/9/64	5248I	578980	--	BF	0	33	34	16	18	SC	119	0.47	56	0.0	13	25.3
nm	6-TC-36B	28/9/64	5248I	578979	--	TS	2	13	11	--	NP	SM	117	0.38	44	0.3	14	25.5
nm	6-TC-36C	28/9/64	5248I	577979	--	T	0	9	--	--	NP	SP-SM	149	0.77	115	0.9	15	20.7
nm	6-TC-36D	28/9/64	5248I	576979	--	LS	2	6	--	--	NP	SP-SM	208	1.13	235	0.0	15	7.0
nm	6-TC-36E	28/9/64	5248I	575979	--	UF	0	8	--	--	NP	SP-SM	171	0.87	149	0.3	15	9.0
nm	6-TC-37A	29/9/64	5149II	059082	--	BF	0	60	30	12	18	CL	96	0.57	55	1.0	15	18.2
nm	6-TC-37B	29/9/64	5159II	059082	--	TS	3	63	36	13	23	CL	128	0.38	49	0.3	13	17.3
nm	6-TC-37C	29/9/64	5159II	059081	--	T	0	46	20	12	8	SC	68	0.60	41	0.4	15	16.8
nm	6-TC-37D	29/9/64	5149II	058080	--	T	0	71	29	14	15	CL	81	0.42	34	0.0	15	25.0
nm	6-CR-100	6/10/64	5448IV	986980	A24	--	--	41	26	16	10	SC	290+	--	tf	--	--	16.4
nm	6-CR-101	6/10/64	5448IV	987982	A24	--	--	31	48	31	17	SM	221+	--	--	--	--	16.4
nm	6-CR-109	7/10/64	5448IV	885997	A24	--	--	27	--	--	NP	SM	178+	--	tf	--	--	13.9
nm	6-CR-113	7/10/64	5349II	128096	A22	--	--	36	21	17	4	SM-SC	177	--	--	--	--	16.6
nm	6-CR-116	7/10/64	5448IV	770991	A24	--	--	60	52	--	19	MH	135	1.10	146	--	--	44.5
9	6-CR-118	8/10/64	5448III	002774	A25	--	--	66	79	44	35	MH	128	0.63	81	--	--	40.0
1	6-CR-119	8/10/64	5448III	979767	A25	--	--	78	57	25	32	CH	--	--	--	--	--	142.0
13	6-CR-120	8/10/64	5448III	969788	A25	--	--	10	--	--	NP	SP-SM	108	--	--	--	--	18.2
1	6-CR-126	9/10/64	5448III	897782	A25	--	--	83	64	36	28	MH	37	0.52	19	--	--	77.6
4	6-CR-127	9/10/64	5448III	895783	A25	--	--	90	67	32	35	CH	56	0.94	53	--	--	57.5
4	6-CR-129	9/10/64	5448III	903820	A25	--	--	71	54	26	28	CH	110	0.58	64	--	--	26.5
13	6-CR-130	9/10/64	5448III	904830	A25	--	--	0	--	--	NP	SP	300+	--	tf	--	--	20.0
4	6-CR-131	9/10/64	5448IV	908835	A24	--	--	38	40	19	21	SC	142	0.59	84	--	--	24.4
nm	6-CR-132	9/10/64	5448IV	882954	A24	--	--	44	43	30	13	SM	203+	0.96	195	--	--	23.5
13	6-CR-133	10/10/64	5448IV	866877	A24	--	--	23	--	--	NP	SM	116	--	--	--	--	13.4
4	6-CR-137	10/10/64	5448IV	900857	A24	--	--	46	49	28	21	SM	127	0.49	62	--	--	30.3
nm	6-CR-139	10/10/64	5448IV	911931	A24	--	--	22	33	19	14	SC	185+	0.45	83+	--	--	21.6
nm	6-CR-140	10/10/64	5448IV	896943	A24	--	--	18	27	19	8	SC	153	--	--	--	--	12.6
nm	6-CR-141	10/10/64	5448IV	89596[illegible]	A24	--	--	49	22	17	5	SM-SC	74	0.46	34	--	--	19.1
1	6-CR-143	11/10/64	5448IV	804875	A24	--	--	68	80	46	34	OH	29	0.49	14	--	--	99.8
2	6-CR-144	11/10/64	5448IV	811869	A24	--	--	71	49	27	22	CL	82	0.73	60	--	--	44.1
4	6-CR-145	11/10/64	5448IV	812917	A24	--	--	75	26	17	9	CL	50	0.64	32	--	--	45.5
nm	6-CR-146	11/10/64	5448IV	757002	A24	--	--	59	38	23	15	CL	290+	0.46	133+	--	--	22.7
9	6-CR-147	11/10/64	5448IV	757993	A24	--	--	47	23	--	NP	SM	170+	0.60	102+	--	--	17.5
9	6-CR-148	11/10/64	5448IV	752981	A24	--	--	50	46	35	11	ML	300+	0.97	291+	--	--	26.2
13	6-CR-149	11/10/64	5448IV	773974	A24	--	--	53	63	47	16	ML	216	1.29	279	--	--	41.5
9	6-CR-150	11/10/64	5448IV	786958	A24	--	--	56	56	43	13	MH	104	--	--	--	--	34.6
nm	6-CR-151	12/10/64	5448IV	790998	A24	--	--	59	60	29	31	CH	213	--	--	--	--	42.8
nm	6-CR-152	12/10/64	5448IV	788991	A24	--	--	44	41	26	15	SM	159	1.23	196	--	--	22.5
nm	6-CR-154	12/10/64	5448IV	783984	A24	--	--	61	57	44	13	MH	94	1.52	143	--	--	52.8
11	6-CR-157	13/10/64	5448IV	791948	A24	--	--	66	61	46	15	MH	150	0.82	123	--	--	46.4
9	6-CR-158	13/10/64	5448IV	784968	A24	--	--	56	57	44	13	MH	130	0.46	60	--	--	--
nm	6-CR-159	13/10/64	5448IV	807970	--	--	--	58	36	20	16	CL	229+	0.59	135+	--	--	19.0
nm	6-CR-160	13/10/64	5448IV	811969	--	--	--	46	37	21	16	SC	133	1.14	152	--	--	24.6
nm	6-CR-165	14/10/64	5448IV	755009	A24	--	--	40	34	20	14	CL	187	0.64	120	--	--	17.4

(Continued)

Note: All soil strength measurements except sheargraph measurements were made at a 15- to 30.5-cm depth. Sheargraph measurements were made at the surface.

* nm, not mapped.

** Series L708, scale 1:50,000.

† BF, bottomland flat; BD, bottomland depression; LS, lower slope; MS, middle slope; NL, natural levee; T, terrace; TS, terrace slope; SB, stream bottom; UD, upland depression; UF, upland flat; US, upper slope.

†† a_{ur} , shear strength at zero normal load.

‡ α_{ur} , ultimate angle of internal friction.

‡‡ tf, too firm.

Table A6 (Concluded)

Map Class	Site No.	Date Sampled	Location: AMS Map Sheet	Location: Grid Coords	Location: Figure No.	Topographic Position	Slope %	Unified Soil Classification System: Fines % by Weight	Atterberg Limits: LL	Atterberg Limits: PL	Atterberg Limits: PI	Soil Type	Soil Strength Measurements: Cone Index	Remolding Index	Rating Cone Index	Sheargraph: c_{ur} psi	Sheargraph: ϕ_{ur} deg	Moisture Content %
nm	6-CR-168	14/10/64	5448IV	780997	A24	--	--	60	61	44	17	MH	300+	--	--	--	--	44.2
nm	6-CR-171	14/10/64	5448IV	809007	A24	--	--	34	46	28	18	SM	151	--	--	--	--	19.6
nm	6-CR-172	14/10/64	5448IV	826012	A24	--	--	31	43	24	19	SC	235+	0.78	183+	--	--	19.6
nm	6-CR-174	14/10/64	5448IV	845988	A24	--	--	59	44	27	17	ML	120	1.19	143	--	--	30.8
11	6-CR-176	15/10/64	5448IV	805932	A24	--	--	48	55	41	14	SM	108	1.15	134	--	--	44.5
nm	6-CR-177	15/10/64	5449III	977056	--	--	--	65	39	24	15	CL	173	0.79	137	--	--	25.9
nm	6-CR-178	15/10/64	5449III	973084	--	--	--	39	16	--	NP	SM	141	0.11	16	--	--	20.0
4	6-CR-182	16/10/64	5448IV	825930	A24	--	--	36	45	26	19	SC	241+	--	--	--	--	16.2
12	6-CR-183	16/10/64	5448IV	853934	A24	--	--	86	47	28	19	ML	219+	--	--	--	--	--
9	6-CR-184	16/10/64	5448IV	862943	A24	--	--	58	58	43	15	MH	109	0.53	58	--	--	49.0
nm	6-CR-185	16/10/64	5448IV	858957	A24	--	--	86	61	41	20	MH	94	0.76	71	--	--	--
nm	6-CR-186	17/10/64	5448IV	923973	A24	--	--	26	26	19	7	SC	217	--	--	--	--	15.7
1	6-CR-187	17/10/64	5448IV	815892	A24	--	--	69	59	34	25	OH	18	--	--	--	--	91.2
1	6-CR-189	17/10/64	5448IV	832933	A24	--	--	45	56	11	45	SC	53	--	--	--	--	65.9
nm	6-CR-190	18/10/64	5349II	153084	A22	--	--	52	47	28	19	ML	245+	1.00	300+	--	--	20.0
11	6-CR-191	18/10/64	5349II	151067	A22	--	--	83	54	34	25	CH	157+	1.05	165+	--	--	22.6
11	6-CR-194	18/10/64	5349II	124028	A22	--	--	41	28	17	11	SC	202+	1.12	226+	--	--	18.6
11	6-CR-195	18/10/64	5348I	137992	A23	--	--	75	27	18	9	CL	280+	0.75	210+	--	--	17.8
12	6-CR-197	18/10/64	5348I	127948	A23	--	--	0	--	--	NP	SP	207	--	--	--	--	8.4

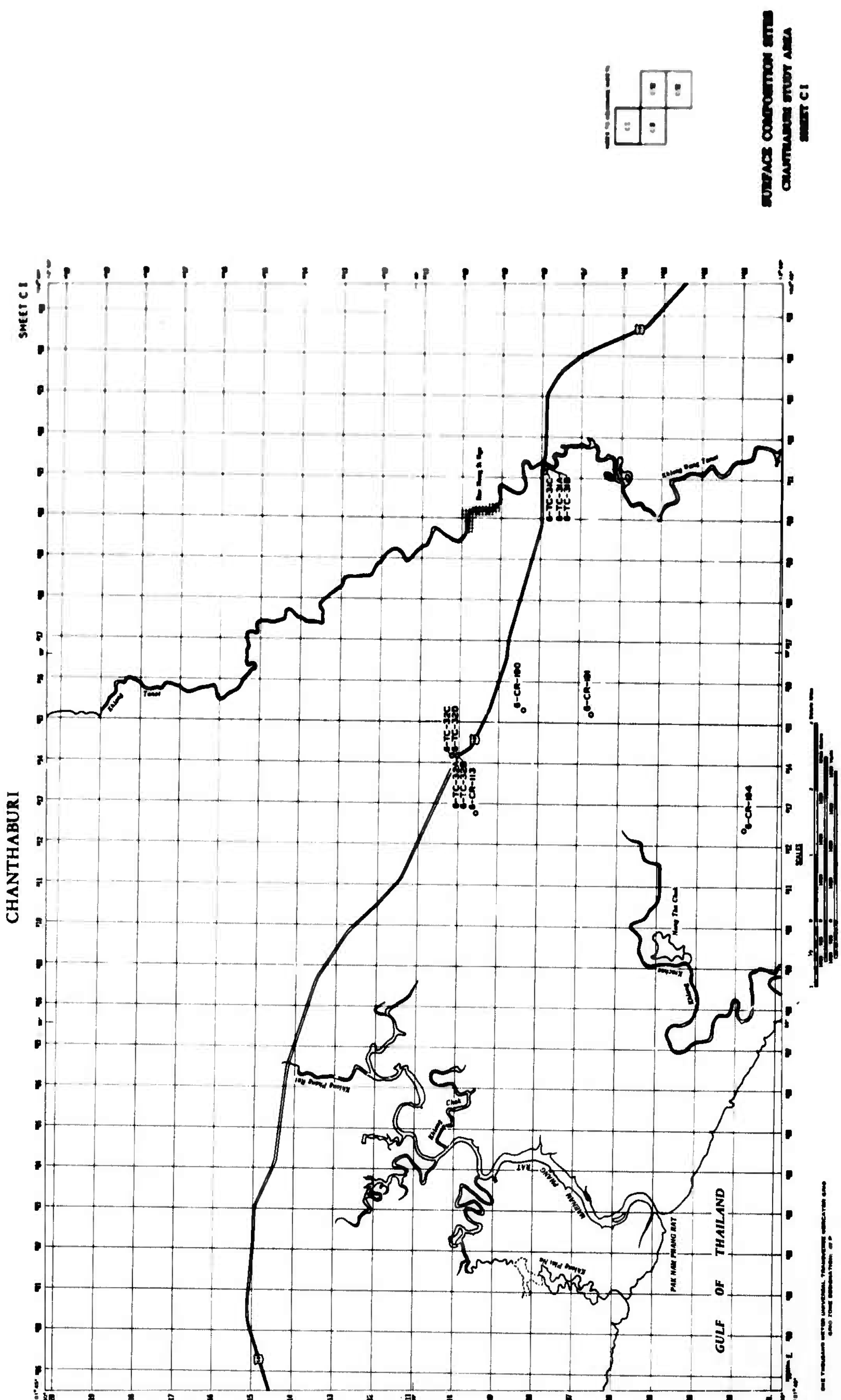

CHANTHABURI
SHEET C I
GULF OF THAILAND
SURFACE COMPOSITION SITES
CHANTHABURI STUDY AREA
SHEET C I

FIG. A22

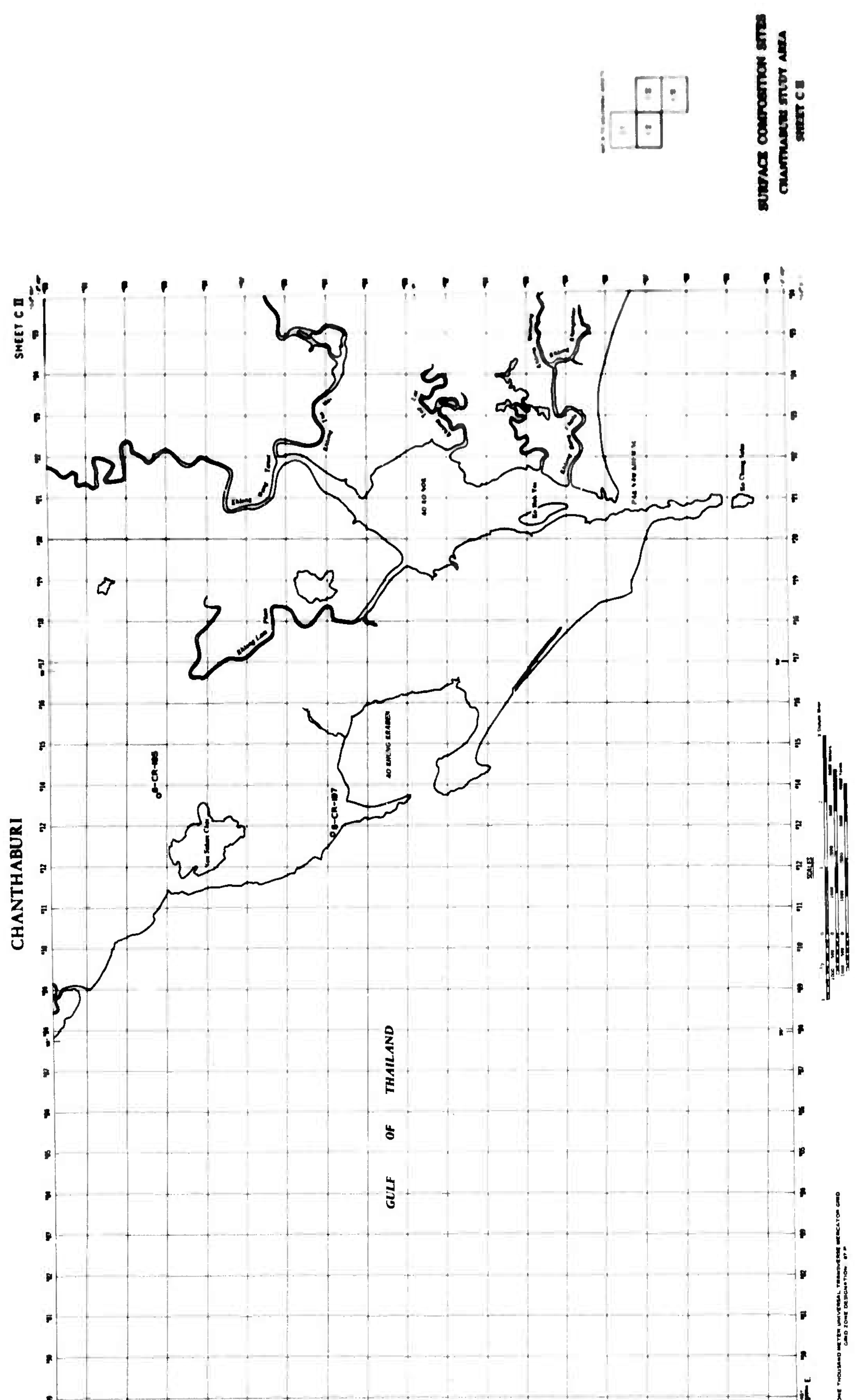

SURFACE COMPOSITION SITES
CHANTHABURI STUDY AREA
SHEET C II
CHANTHABURI
SHEET C II
GULF OF THAILAND

FIG. A23

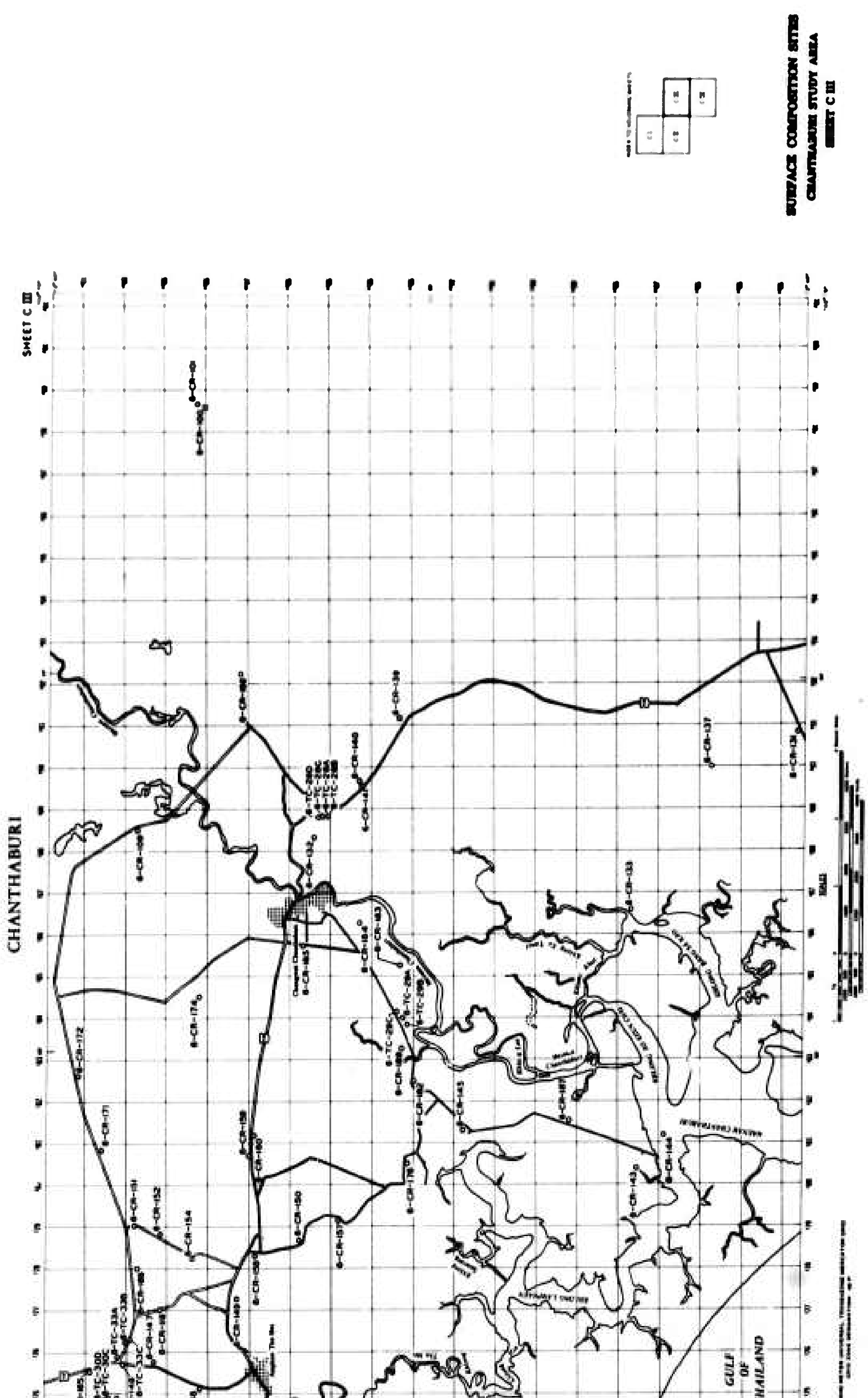

SURFACE COMPOSITION SITES
CHANTHABURI STUDY AREA
SHEET C III
SHEET C III
CHANTHABURI
GULF OF THAILAND

FIG. A24

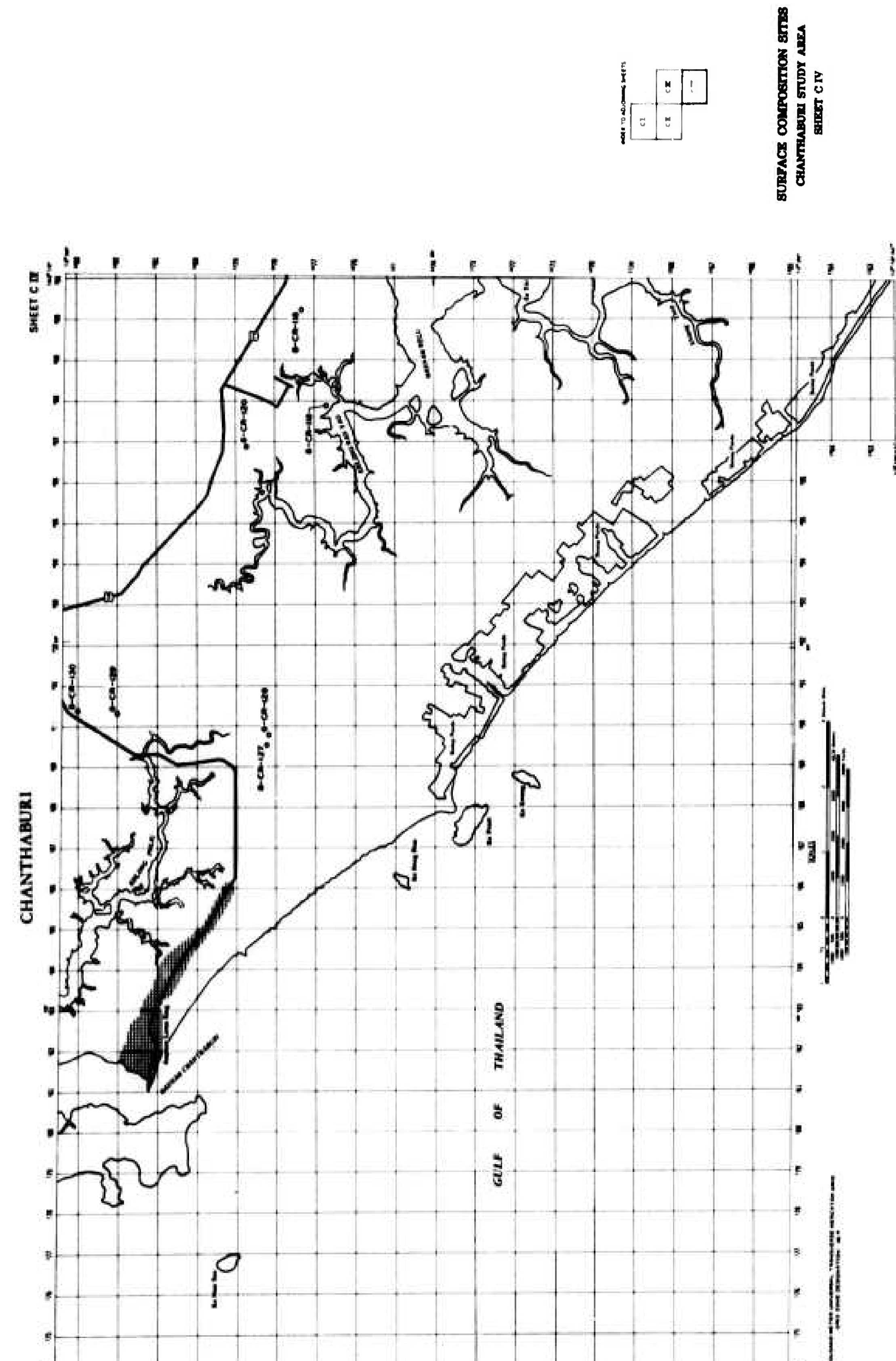

CHANTHABURI
GULF OF THAILAND
SURFACE COMPOSITION SITES
CHANTHABURI STUDY AREA
SHEET C IV

FIG. A25

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Engineer Waterways Experiment Station Vicksburg, Mississippi	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

MOBILITY ENVIRONMENTAL RESEARCH STUDY; A QUANTITATIVE METHOD FOR DESCRIBING TERRAIN FOR GROUND MOBILITY; SURFACE COMPOSITION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Volume II of an eight-volume report

5. AUTHOR(S) (First name, middle initial, last name)

Ramil C. Wright
James R. Burns

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1968	95	14

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	Technical Report No. 3-726
c. Order No. 400	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of U. S. Army Materiel Command.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Advanced Research Projects Agency; Service Agency: U. S. Army Materiel Command, Washington, D. C.

13. ABSTRACT

This volume presents the methods used to collect, tabulate, and analyze basic data on surface composition of six selected Thailand study areas--Nakhon Sawan, Lop Buri, Chiang Mai, Pran Buri, Khon Kaen, and Chanthaburi. Fifteen mapping classes that expressed the different soil mass strength and soil surface strength conditions were established. The criteria used in isolating these classes were (a) that each class be identifiable using air-photo interpretation techniques and (b) that each class exhibit similar variations in strength with moisture content. Areas with equivalent trafficability characteristics in terms of the 15 map classes were delineated on 25 surface composition maps together covering the six study areas. This delineation was accomplished through interpretation of maps and air photos with control data in the form of field and laboratory information. The maps are presented in Volume VIII of this report. A compromise between the desired degree of mapping class refinement and that dictated by the photo-interpretation criteria was necessary because of the nature of the field data. During the mapping program when sample site data were extrapolated to unsampled areas, the degree of mapping refinement was of necessity only fair to low. It is recommended that additional studies be conducted on the use of air-photo identification techniques in classifying soil strength conditions. This approach is believed to be basically sound; however, more field verification of predicted values will help to determine the reliability of this approach.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aerial photography						
Environmental studies						
Mobility						
Soils--strength						
Soils--trafficability						
Terrain analysis						
Terrain--Thailand						
Thailand						